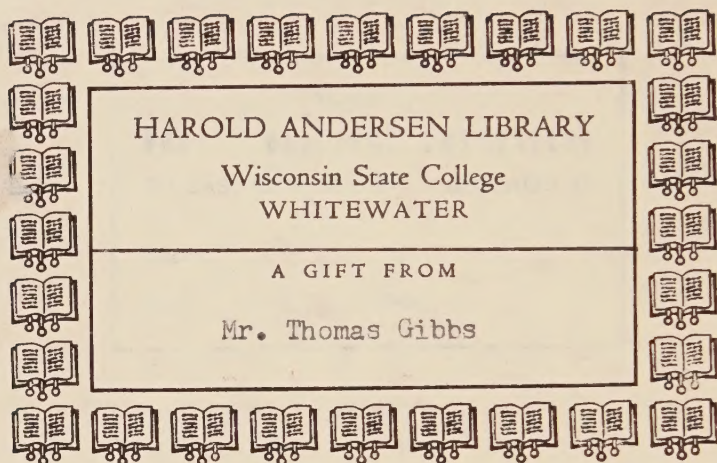
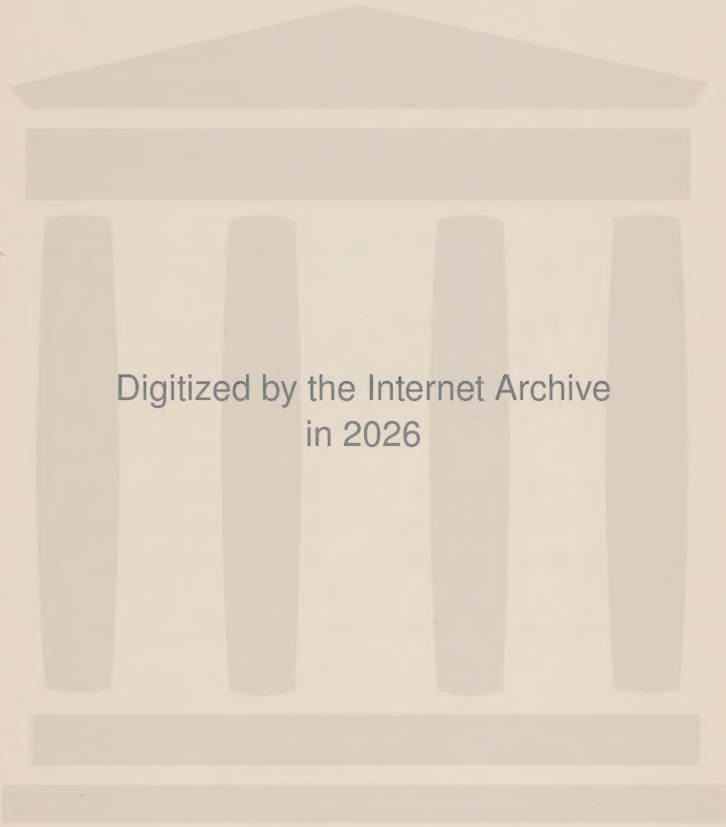


THE
ABRASIVE HANDBOOK

By Fred B. Jacobs



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The Abrasive Handbook

A complete reference work on abrasives
and grinding practice for the manager,
abrasive engineer, superintendent, fore-
man, grinding machine operator and
student

Compiled By

FRED B. JACOBS

Editor, *Abrasive Industry*, and author of
Abrasives and Abrasive Wheels, *Cam*
Design and Manufacture, *Production*
Grinding, and *How to Regrind Auto Parts*

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INTRODUCTION

Grinding plays a most important part in present-day industry for without it the cost of many everyday commodities would be prohibitive. For example, without the modern grinding machines and wheels it would be impossible to manufacture low-priced cars. Without the help of abrasive engineers such vehicles would cost several thousand dollars each. The abrasive industry has developed rapidly during the past quarter of a century and during this period there have been evolved many interesting and economical ways of applying grinding processes.

Data pertaining to abrasives is not always obtained readily, although the splendid work done by the publishers of *Abrasive Industry* has aided materially in spreading abrasive knowledge. The data contained in this handbook represent a painstaking collection covering a period of many years.

As a reference work for works managers, chief engineers, designers, abrasive engineers, grinding-room foremen, and grinding-machine operators, it is the hope of the editor that this book soon will be recognized as a standard covering the best current practice. This book points out how many classes of work can be ground advantageously and it answers practically most questions which confront the users of abrasive materials or grinding machines. It stands by itself as being the only work of its kind ever published.

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SECTION I

ABRASIVE MATERIALS

Abrasive materials are classed into two groups, natural and manufactured. The natural abrasives are emery, corundum, quartz, flint, garnet, diamond, tripoli, diatomaceous earth, sandstone, pumice, and natural sharpening stones. The manufactured abrasives are carbide of silicon, aluminum oxide, glass, and the metallic abrasives such as steel wool and steel shot and grit. Following is an alphabetical list of the abrasives described in this section:

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ABRASIVE MATERIALS

ABRASIVE GLASS

Glass has been utilized as an abrasive for a number of purposes. Many years ago, before the advent of manufactured abrasives, glass was considered a good medium for grinding locomotive throttle valves in their seats, for grinding brass valves for various purposes, etc. The glass was powdered very fine and used with water or oil.

In England abrasive glass is used in considerable quantities for coating abrasive paper and cloth, taking the place of the flint used in the United States. As the British supply is obtained from old liquor bottles, it is cheap and abundant. In the United States, however, glass coated paper has never been a serious competitor with flint and garnet. This is due probably to the superior cutting qualities of these natural materials and to large sources of the raw product. However, under certain conditions glass paper has been known to give good results. It also is used to quite an extent in Canada.

ALUMINUM OXIDE

This material, which is also termed manufactured alumina, is an electric furnace product made by fusing materials high in alumina, such as bauxite. It has also been made from emery, resulting in the so-called German iron-free corundum. Manufactured alumina also is made from corundum. This product is used extensively for making cool cutting wheels for specific grinding operations. Bauxite is used principally for making aluminum oxide as it can be mined cheaply, while its alumina content is high.

Bauxite is a clay like material, taking its name from the village of Les Beaux in Southern France where it first was observed. It never is found in a crystallized state. Its color runs from light yellow to deep red. Its constituents are aluminum oxide, iron oxide, silica and titanitic acid. It is thought to be a decomposition of an igneous rock. It is mined in open cuts, calcined to remove the excess of moisture and shipped to abrasive plants in carload lots.

In the manufacture of aluminum oxide at the plant of the Carborundum Co., the following process is followed:

The furnace is a simple affair consisting of an outer shell

ABRASIVE MATERIALS

which rests on a base, while two electrodes supply the current. While the shell is cooled by water circulation, it does not contain a refractory lining as the charge forms this itself. The furnace is mounted on wheels so that it can be moved from under the electrodes after the burning operation is completed.

In making up the charge, the bottom of the furnace first is lined with a carbon and tar mixture. Then a layer of bauxite is introduced and the electrodes lowered to rest on it. A path of graphite then is laid between the electrodes. This forms a good passage for the current, but as soon as the bauxite is melted it forms its own conductor. The current is turned on and the charge brought to a molten state. The current is alternating, 6000 amperes at 100 volts.

After the first layer is melted another layer is put in place and the electrodes raised. This process is continued for about 36 hours at which time the furnace is full. During the melting process the oxide of iron and silica in the raw material unite and form ferro silicon so that the abrasive is practically pure. After the furnace has cooled off the outer shell is removed and the ingot taken out. It is broken up under a skull cracker and next passed through an ore crusher. Next it goes through a magnetic separator. Subsequent operations consist of feeding the material through a roller crusher after which it is graded into various sizes.

Aluminum oxide varies in color from a light purple to a dark brown. A special variety is almost white in color. Aluminum oxide is used for making grinding wheels for finishing materials of high tensile strength. It is used in grain form for setting up polishing wheels, coating abrasive paper and cloth, and to a certain extent for finishing stone, glass, etc.

The ordinary variety of aluminum oxide is used for general steel grinding on both rough and precision work, while a refined variety is used largely for grinding alloy steels, for cutter sharpening, etc.

Aluminum oxide first was made in 1837 by M. A. A. Gaudin who was performing experiments to produce artificial rubies. Other experimenters took up the work from time to time laying the foundation for the latter day investigators who produced the material on a commercial basis. Perfection of this abrasive

is due to American genius chiefly to that of Charles B. Jacobs and Frank J. Tone.

CARBIDE OF SILICON

Carbide of silicon is a manufactured abrasive, a chemical composition of two elements, carbon and silica. It is made in an electric furnace of the resistance type, the ingredients forming the charge being coke, salt, sawdust and sand. Coke supplies the element of carbon and sand that of silica. The salt brings about certain reactions in the manufacturing process, while the sawdust makes the mass porous so that the gas generated finds a ready means of escape.

Ordinary carbide of silicon furnaces are approximately 50 feet long, 10 feet wide and five feet high. The walls and sides are brick, while the top is open. The electric terminals run through the end walls. They are carbon rods three inches in diameter arranged in bundles of 60. The spaces between the rods are packed with graphite. The outer ends are capped with copper to form electrical connections.

The furnace charge is made up of 34 parts coke, 54 parts sand, 10 parts sawdust and 2 parts salt. These materials are mixed by mechanical means and usually they are brought to the furnace by a conveyor. In charging, enough of the mixture is placed in position to fill the furnace up to the level of the electrodes. A trench is dug between the electrodes and filled with granulated coke. This allows a free passage of current when the burning operation is started. The furnace is then filled completely and the current turned on. This current is alternating, 190 volts and 6000 amperes. The resistance lowers as the furnace charge heats and after four hours of operation it remains constant at 125 volts, 6000 amperes. The sawdust burns out first and then carbon monoxide is given off, which burns with a yellow flame. As the action goes on the mass shrinks which necessitates the adding of new material. About 36 hours are consumed in the burning operation. Then the furnace is permitted to cool for a day after which it is broken open. The top crust is practically unaltered and under this is found a layer of amorphous carbide of silicon. Under this is the pure crystallized material of commerce. At the center is found a mixture of carbide of silicon and graphite.

ABRASIVE MATERIALS

The heat necessary is estimated at 7500 degrees Fahr., which is sufficient to turn the core into practically pure graphite.

The outer layer of material, that is the amorphous carbide of silicon, for many years was thought to have no commercial value. Later it was discovered that this material has high refractory properties so that today it forms a valuable by-product. Carbide of silicon is of various colors from green to gray. The color is not an index of its value. Carbide of silicon has a well defined crystalline structure and it is exceedingly hard and sharp. It is nearly if not quite as hard as a diamond. Its specific gravity is approximately 3.18.

Carbide of silicon has never been found naturally, the reason probably being that the heat to form it is so near that necessary to form graphite that the latter material only was formed when the earth cooled off.

Carbide of silicon is used for the manufacture of grinding wheels, being especially valuable for grinding cast iron and brass. It also is an economical abrasive for grinding stone, glass, etc. In grain and powder form it is used for stone finishing, glass grinding, etc. Coated on paper and cloth it is used for a diversity of purposes such as leather finishing, paint rubbing, etc.

Carbide of silicon was discovered by Edward G. Acheson in 1891 while he was experimenting with a small electric furnace. This material first was used for polishing precious stones, at which time it sold for \$880 a pound.

CORUNDUM

This mineral is an impure form of the ruby, a composition of alumina and oxygen, Al_2O_3 , with impurities such as silica, ferric oxides, etc., and combined water. Some 50 years ago it was considered a comparatively rare mineral but now it is known to exist in several parts of this country. Large deposits have been worked (and worked out) in Hastings county, Canada. During the World war, immense reserves of this mineral were opened in the Transvaal district of South Africa.

Corundum in reality is a pure form of emery as its chief constituent is alumina. Its crystals present no true cleavage, but parting planes are present. If these are too numerous,

however, so as to be present in the individual grains of which a grinding wheel is composed, such a corundum is low in efficiency. An ideal corundum for abrasive wheel manufacture is one wherein the dull grains will break with an irregular to a conchoidal fracture. The hardness of corundum varies from 8.8 to 9. It is found in three forms called boulder, crystal and grain corundum.

At the present time the principal deposits in the United States worked for commercial purposes are in North Carolina near Franklin. This property is known as the Corundum Hill Mine and is controlled by the Hampden Corundum Wheel Co. This material is found in small crystals running through decomposed rock. As it is cleaned readily, it forms a valuable source of abrasive supply. In the United States corundum also has been found in Maine, Massachusetts, Connecticut, New York, Pennsylvania, Delaware, Virginia, South Carolina, Tennessee, Georgia, Colorado, Montana, California and Idaho. In Canada the chief deposits were found in Renfrew county, Ontario. As previously stated these deposits have been worked out. However, operations now are being carried on in working over an enormous pile of *tailings*, the residue left by cleaning operations of other days, so that a source of supply of this material still is available and may continue for some years to come. In speaking of corundum in general it can be stated that it crystallizes in the rhombohedral division of the hexagonal system and under the head of crystal corundum is included all the crystal varieties of corundum which occur in block corundum or in sand and gravel. The following are typical analyses of corundum from various localities:

CORUNDUM ANALYSIS

	1	2	3	4
Al ₂ O ₃	96.92	98.79	95.51	95.75
SiO ₂ .....	.....	.90	1.45	1.75
FeO ³ .....	.....	.75	.88	1.00
H ₂ O	2.43	.78	.74	1.45

No. 1 is corundum from Hastings county, Ont., analyst—Wells.

No. 2 is corundum from Corundum Hill Mine, N. C., analyst—Emerson.

No. 3 is corundum from Laurel Creek Mine, Ga., analyst—Emerson.

No. 4 is corundum from Northern Transvaal, South Africa, analyst—Green.

Various methods are employed for cleaning and preparing

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corundum grain for the market, and the following description of the methods followed at the plant of the Zoutpansberg Grain Corundum Co., Ltd, as described by A. L. Hall, in the *South African Journal of Industries*, is typical of up-to-date practice. Mr. Hall is assistant director of the Geological Survey, Union of South Africa.

The corundum deposits are found about 400 feet from the company's mill. They occur in reef as well as in eluvial form. The reefs are opened up through a series of surface workings consisting of irregular pits, while trenches and short cross cuts expose a solid reef to a depth of 60 feet. The ore forms vertical bodies up to 12 feet thick. It is composed of coarse, white plumasite (feldspar corundum rock) carrying from 15 to 60 per cent corundum. The remainder is almost entirely feldspar with a small amount of black mica, magnetite, etc. The water supply comes from a driven well located 500 feet from the mill. This well furnishes not less than 180,000 gallons per day which is ample for all milling operations. A 54-horsepower gas engine generates power for pumping water, running the mill and working the dynamo for the magnetic separator and also for electric illumination. The milling operations include crushing, concentrating and grinding.

The ore arrives at the mill as coarse, gravelly material mixed with earthly debris, but including larger blocks. These are reduced to about half the size of a man's fist in a 12-inch Robey stone crusher. The ore then is crushed by five stamps, each weighing 1500 pounds, in a continuous supply of water. The product passes out through a screen with eight meshes to the linear inch to a Frenier pump.

This pump lifts the crushed material to a callow screen, in which a screen of 20 mesh furnishes an oversize and under-size. The oversize passes to a 3-compartment Hartz jig, the receiving compartment of which furnishes pure corundum. This is drained into settling vats, then dried and finally passed through a magnetic separator and on to a classifier. The middle compartment produces less pure corundum, to which particles of feldspar adhere. These are so-called *middlings* and they are returned to the stamps. The third compartment yields almost pure feldspar as waste. The undersize material from the callow screen goes to a Spitzkasken table and then to two Wilfley tables

and after drying to the magnetic separator and classifier. Slimes from the Wilfley tables go to settling pits.

Concentrates from both the jig and Wilfley tables are sent to the magnetic separator in which two endless canvas belts pass between a powerful electromagnet so that the magnetic particles are attracted to the upper belt and thrown out. Corundum remains on the lower belt, it being discharged automatically onto the classifier.

This device is a long, gently pulsating framework, set on an incline. It embodies various sizes of screen, the finest being situated next to the discharging belt from the separator. As the grains pass down the series of screens they are automatically sized into predetermined numbers. When they reach an opening large enough to accommodate them they drop through the screen into receptacles placed to receive them. Three distinct grades of corundum are recovered, ranging in size from 10 to 100 mesh. The product is put up in bags of 112 pounds weight each. The grain sizes are 10, 14, 20, 24, 30, 35, 40, 50, 55, 60, 65, 70, 75, 80, 100. The finished product is a greenish-gray, clean and uniform granular material.

As an abrasive, corundum has many uses. According to British practice, it makes excellent grinding wheels for finishing materials of high tensile strength. It also is used for coating abrasive cloth, and to some extent in grain form for setting up polishing wheels. In the finer numbers, it enjoys an excellent sale among the lens-making industry, it being considered an ideal material for grinding glass.

CROCUS COMPOSITION

A material composed of crocus mixed with a suitable binder and molded in cake form. It is used for bringing up the high luster seen on iron and steel parts such as cutlery. This material also is used on tin and similar soft materials.

DIAMONDS

Diamonds are of two general types, the white or gem variety and the black or carbonado stones. Bort diamonds as used for grinding wheel truing are in reality imperfect gem stones which because of flaws, construction characteristics, etc., cannot be cut into gems.

Diamonds are found in India, South America, South Africa,

New South Wales, Borneo, British Guiana and in the United States. They are found in the craters of extinct volcanoes and also in river beds or in localities where once rivers existed. Such stones have been washed down from mountain ranges for it is generally conceded that diamonds were formed in volcanoes only. Why this is so is not clear, but it is the consensus of opinion among geologists who have made a deep study of the subject. Diamonds run in color from pure white to dark brown. The specific gravity of the diamond is 3.5, while its hardness is 10 on Moh's scale. It is conceded to be the hardest substance known, but this fact sometimes is disputed. Diamonds crystalize in the cubic system, generally as octahedrons.

The majority of diamonds are found in South Africa the more important mines being the Premier, Kimberley and De Beers. The output of diamonds is controlled by a British syndicate which puts only so many stones on the market annually.

In the South African mines, the stones are found in what is technically termed *blue ground*. Formerly this material was spread out above ground for weathering before the diamonds were sorted out, but of late years a more direct method has been employed. In general about four tons of blue ground must be mined to produce a carat weight of diamonds. The workings extend underground for a great distance, often to a depth of 3000 feet or more.

The blue ground is washed to separate worthless material from the gems and a further concentration follows on pulsating tables that are greased with vaseline. Sorting follows and it is here that the gem stones are recovered from the bort. The percentage of bort may run anywhere from 10 to 70, depending on the workings. The process followed in working *river workings*, as they are termed, is simple. The soil is sifted, the diamonds sorted out and later classified. Diamonds have been found in the United States in Arkansas. These stones are small but of great purity. These workings, however, do not institute an important factor in the diamond market.

Carbonado, or black diamond, is found only in Brazil in the state of Bahia. Carbonado is in reality an imperfectly crystallized form of diamond. These stones are excellent for wheel truing, but they are more expensive than the bort variety. Comparatively large pieces are found. These are crushed by hydrau-

lic pressure to form small stones for wheel truing and other mechanical purposes. Carbonado possesses no cleavage lines and breaks with a granular fracture.

Ballas diamonds are found in Brazil, as well as in South Africa. They are very rare compared with other diamonds. They are nonporous, round in shape and consist of innumerable, well-formed minute crystals grouped in concentrical formation around a nucleus. On account of their structure they have no defined cleavage planes and are invariably of extraordinary hardness. Strictly speaking they are not harder than the best carbons, but they are tougher on account of their structure. Considered in a general way ballas have much in common with carbons. Brazilian ballas rank first in quality and are chiefly used for mineral boring and grinding wheel truing. Ballas stones from the cape region of South Africa are considerably less tough than Brazilian stones but, nevertheless, they are superior to bort in that they are less fragile, having no planes of cleavage. Round, white diamonds often are wrongly described as ballas, but these are merely bort of round shapes which, being easily cleaved, can in no wise be used in place of ballas.

Bort stones, as used for grinding wheel truing, are more or less transparent crystals of white appearance occurring in varied shapes and sometimes in twin and multiple crystal forms. By far the greater part of the world's output of bort is now obtained from South Africa where it is mined in an heterogeneous eruptive rock known as blue ground, contained in volcanically formed pipes extending vertically downward to great depths. The De Beers and Kimberley mines yield on an average of $\frac{1}{2}$ -carat of diamond per ton of blue ground while other mines, which nevertheless are still profitable, yield only a quarter of this amount, or $\frac{1}{8}$ -carat per ton of raw material.

The price of bort is in strict keeping with their size and quality. The latter depends in the first place on hardness and further on shape, structure, soundness and color. Brazilian bort is said to rank first in point of hardness followed in approximate order by Australian, South West Africa and Cape. The most desirable Cape diamonds are said to be the Jagersfontein and "river" followed by the Premier, Balfontein and Wesselton. Unfortunately Australian and South West African stones

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are recovered only in small size not over $\frac{3}{4}$ -carat, and the Brazilian rarely exceeds 3 carats.

DIATOMACEOUS EARTH

The following data regarding diatomaceous earth were prepared by W. C. Phalen: Diatomaceous earth is more commonly known as infusorial earth. It sometimes is referred to by its German name, kieselguhr. It also is, though erroneously, called tripoli. It is composed of the siliceous remains of minute aquatic plants known as diatoms, which are of minute proportions, as a general rule, and have to be identified chiefly by the aid of the microscope. The organic matter of these plants has long since disappeared from most of the deposits, but there are notable exceptions, as in California.

These low forms of plant life secrete silica much after the same manner as mollusks secrete lime, and thus build up their shells. It is this part of the plant which makes up the formations found in nature. The siliceous parts accumulate on the bottoms of the bodies of water in which the plants lived, and in time attain considerable thickness, and become of economic importance. The diatoms may live in either fresh or salt water and under widely varying conditions of depth, pressure and temperature. For example, they have been found in the depths of the Atlantic ocean, and are known to occur in the warm springs of Yellowstone National park, to cite two extremes of temperature, pressure, and difference in the character of the water. The material is now in process of formation and although it has in times past been formed in very different epochs, it is especially abundant in the Tertiary and most of the known beds of great thickness are of this age.

In chemical composition, diatomaceous earth is a hydrous silica or opal, but as a rule it contains a considerable quantity of earthy impurities. A simple test, taken in connection with other distinguishing characteristics, is that when touched with hydrochloric acid it does not effervesce. Sometimes analyses from widely separated localities have a great similarity of composition as shown in the first three analyses in the following table:

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ANALYSES OF DIATOMACEOUS EARTH

	1	2	3	4	5	6	7	8
	Percentages of Components							
Silica, SiO_2	80.53	80.66	81.53	75.68	65.62	86.92	72.50	86.89
Alumina, Al_2O_3	5.89	3.84	3.43	9.88	.....	4.27	11.71	2.32
Iron oxide, Fe_2O_3	1.03	.....	3.34	2.92	.....	.....	2.35	1.28
Lime, CaO	0.35	0.58	2.61	0.29	.....	1.60	0.32	0.43
Magnesia, MgO} .....	.....	.....	.....	0.69	.....	Trace	0.83	Trace
Potash, K_2O} .....	.....	.....	1.16	0.02	.....	2.48	1.88	3.58
Soda, Na_2O} .....	.....	1.43	0.08	.....	.....	.....	.....	.....
Water, H_2O	12.03*	4.01*	6.04*	.....	11.00	5.13	9.54	4.89
Nitrogenous matter and moisture .....	.....	.....	.....	9.21	.....	.....	.....	.....
Total	99.83	99.09	99.54	98.77	.....	100.40	99.13	99.39

*Water and organic matter.

Where the different types of infusional earth, noted above, are found:

1.—Lake Umbagog, N. H.

2.—Morris county, N. J.

3.—Pope's Creek, Md.

The foregoing three analyses are quoted from *The Nonmetallic Minerals*, second edition, by G. P. Merrill.

4.—Darton, N. H.

5.—Soft diatomaceous shale, Harris, Santa Barbara county, Calif., W. T. Schaller, analyst.

6.—Porcelain diatomaceous earth, Santa Barbara county, Calif.

7.—Soft diatomaceous shale, Orcutt, Santa Barbara county, Calif., W. T. Schaller, analyst.

8.—Monterey, Monterey county, Calif.

As an abrasive, diatomaceous earth is used in the manufacture of polishing compositions, often being marketed under the name of tripoli. It is considered to be a much purer form of silica than true tripoli. It is used on buffing wheels for cutting down before final polishing. This material has many other uses aside from its application for abrasive purposes.

In preparing the earth for industrial use, it first is roasted to expel as much water and organic matter as possible. It then is transferred to a furnace and is heated to a moderately high temperature, but its porosity must not be destroyed by over heating. Then it is finely ground between rollers, sifted, and sacked to prevent re-absorption of moisture. For certain purposes, it is only necessary to give it a prolonged drying at a high temperature prior to grinding and sifting.

In Santa Barbara county, Cal., the material is broken in open air quarries and as mined contains a considerable percentage of moisture. After 40 or 50 days of drying, the material still contains a small amount of moisture, approximately 5 per cent.

One of the deposits near Lompoc, Cal., that of the Celite Products Co., formerly the Kieselguhr Co. of America, comprises extensive beds of soft white earth in a very pure state, both thin and massive. These form a cap over the hills and overlie brown siliceous shale and are comparable to them. This material is quarried in open cuts. It is removed in large blocks and is air dried in the quarry. It takes from 40 to 50 days to reduce the water content, which ranges from 45 to 5 per cent by weight. It then is hauled by motor trucks to the plant at Lompoc where it is ground to powder and transferred to the different warehouses by a pneumatic system. When blocks are required, the material is transported in its natural state direct from the quarry, sawed to the required sizes, and dried before shipment.

On account of the quantity of absorbed surface water in the diatomaceous earth, it is necessary that it be split into convenient blocks for drying.

Aside from the California deposits previously mentioned, diatomaceous earth is found in Maine, New Hampshire, Massachusetts, New York, New Jersey, Maryland, Virginia, Florida, New Mexico, Nevada, Oregon, Idaho and Washington.

EMERY

Emery is a mixture of aluminum oxide and iron in the form of magnetic or hematite. In appearance it resembles iron ore somewhat, being of a dense granular construction. In reality it is an impure form of corundum. It has been used for abrasive purposes since remote times. The principal emery deposits of the world, listed in the order in which they were discovered are the Grecian Isles, Massachusetts, Turkey in Asia, and New York State.

The most important deposits of the Grecian Archipelago are found on the island of Naxos. Here the emery occurs in large blocks. Some of the deposits occur in white marble. The north and east ends of the island contain the most valuable deposits. According to the United States Geological survey, the best grade of ore is obtained from Vothrie, located nine miles from the coast. Another important deposit is at Apperonthos, seven miles inland. Emery also is found near Yasso in the southern part of the island. It occurs in abundance in the form of boulders so that there is little need to mine the

hard rock. An excellent quality of emery also is found on the island of Nicaria, but the deposits are not extensive. The island of Samos also furnishes excellent emery. Naxos emery is dark gray with a mottled surface. It often occurs with blue particles of corundum which are recognized with the naked eye. Emery from Nicaria sometimes shows a laminated structure. It is dark blue in color and often mottled. Nicaria emery is quite compact. Samos emery is of a uniform dark blue color being found both in coarse and fine-grain forms.

Mining operations in the Grecian Isles are of a primitive character. Blocks of ore, which are not too large, are transported in their natural condition to the coast while larger blocks are broken by sledge blows, usually after they are heated for several hours and cooled suddenly by the application of water. This causes the ore to fracture.

Importing work to facilitate the mining and marketing of Naxos emery was begun during 1923. An aerial cableway and narrow gage lines have been constructed at an approximate cost of \$120,000. The funds were supplied by the National Bank of Greece. The improvements will increase the production of Naxos emery by 20,000 tons per year, the Greek government to be paid one pound, sterling, for each ton of ore mined to pay off the loan. The exploitation of Naxos emery now is confined to recognized companies only. As emery generally is brought to the United States in the form of ballast, the transportation costs are moderate. This is one reason why the foreign product can compete successfully with that of the United States. According to some authorities, however, Grecian emery is considered superior to the American product, but this is a question of conjecture.

Turkish emery is obtained from the province of Aidin in Asia Minor, which embraces practically the entire basins of the Sarabat and Mender rivers. Extensive deposits have been worked on the Gumush-Dagh mountain and on the slopes of Ak Sivri, a mountain about 125 miles distant. The former of these deposits is approximately 12 miles east of the ruins of Ephesus. The latter deposit is described by J. Lawrence Smith as the Kulah district. Emery also has been found in small quantities near Adula, a town about 15 miles east of Kulah, and also at Manser, about 24 miles north. Also it occurs at Allahinan-Bourgs, about 20 miles south of Smyrna.

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The deposits of Turkish emery rest on mica slates, schists and gneisses. This emery always occurs in limestone or marble; no traces of it having been found associated with other rocks. It occurs in irregular pockets which sometimes are 300 feet long and 200 feet wide. The foregoing varieties of Turkish emery vary in appearance. The Gumush-Dagh usually is in fine grains of a dark blue to purplish color. It is quite like some varieties of magnetite. The interior of masses of this emery usually are free of mica. The Kulah emery is coarser grained and much darker in color than the Gumush-Dagh. On its external surface the Kulah emery sometimes resembles the mineral, chromite. The Turkish emery deposits were first brought to general notice in 1847 by Dr. J. Lawrence Smith.

The emery deposits of Massachusetts, located in Chester, were discovered in 1830 while excavating for a railroad bed. The deposit was taken for iron ore and a blast furnace was erected on the site. However, difficulty was encountered in smelting the ore and the project was abandoned. In 1864 Dr. H. S. Lucas acquired the property and began to work it as an emery mine on a commercial basis. This emery is associated with amphibolite and serpentine and as the veins reach several hundred feet under ground, extensive tunneling is necessary. This mine has not been worked for some years.

Emery deposits in the vicinity of Peekskill, N. Y., are being worked at the present time and the product is said to be adapted to a number of abrasive uses. It is not known for a certainty when these deposits were opened. However, the veins have been worked successively by several companies since 1883. At least three important emery mills today are crushing this ore. This emery is termed Peekskill ore and according to the New York State geologist it is a mixture of corundum, spinel and magnetite with more or less of the silica minerals that are found in the wall rocks. Spinel (hercynite) is associated with the magnetite and its occurrence may account for the high alumina percentage. An analysis of the Peekskill emery made by the Columbia University laboratories is as follows:

Material	Per Cent
Alumina	50.10
Iron Oxide	28.17
Magnesia	4.31
Silica	14.32
Lime	0.84

T. J. Ellis of the firm of Smith & Ellis, miners of this ore, assumes that the foregoing analysis includes the spinel content with the percentage of iron itemized. According to Mr. Ellis, actual tests after the emery has been crushed and graded reveal a grit with breaking qualities that furnish grain shapes particularly adapted to sharp and rapid cutting.

The general method followed in working the Smith & Ellis mine is that similar to quarrying stone. The deposits are full of seams and shakes so that they can be opened by explosives very readily. The larger pieces are broken by sledge blows to lifting sizes and trimmed of any silicate rock that clings to them. The older method followed in the Peekskill district was to follow an emery vein into the ground where it was drilled and blasted and a wheelbarrow full of ore taken out at a time. The quarrying method is more economical. The Smith & Ellis workings are trenched so that automobile trucks can be backed into the openings and loaded readily.

In common with other natural products, emery ore varies in a number of characteristics. This is true of specimens from different mines and also of the products of the same mine. Emery ore must be selected and graded carefully to insure a reliable product. The shape of the grains after crushing have a great deal to do with the working efficiency of any emery.

Emery has a specific gravity of 3.7 to 4.3, while its percentage of aluminum oxide runs from 30 to 70. In general, the higher the alumina content, the better the emery. Emery is used for a diversity of purposes. In the form of grinding wheels it is used for snagging heavy steel and malleable castings or for backing up manufactured abrasive wheels sold for this purpose. Emery is particularly adapted to this work as its grains hold to the bond with a tenacity that is productive of long wheel life. In the form of coated paper and cloth large quantities of emery are used in various industries. In grain and powder form emery forms an excellent polishing, large quantities being used for setting up polishing wheels for finishing practically all metals. It also is used for glass grinding. At one time emery was the only alumina abrasive available and in spite of the serious inroads made by the artificial abrasives, there is today more emery consumed than ever before. This, of course, is due to the rapid advancement made in abrasive practices during the past decade.

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EMERY CAKE

A composition made of fine emery with a suitable binder and used for treating buffing wheels for cutting down operations. It is a sharp fast cutting composition for the work in question and is used on rough castings, aluminum, sheet metal, etc. It generally is furnished in grits of 120, 140, 150, 160, 170, 180, F, FF, and FFF. Emery cakes weigh about three pounds each. Fine-grit emery cake is used for treating polishing wheels for oiling operations.

EMERY STRING

This material is stout flax cord impregnated with flour emery and a grease binder. It is used in sewing machine factories for "stringing out" holes in thread guides and in musical instrument manufacture for removing burrs from holes in pegs and tail pieces. The material comes in several sizes, although they have not been standardized. The demand for this material is not great.

FLINT

This material is a very hard mineral substance with a specific gravity of 2.6. Its chief component is silica. It has been used from remote times. Due to the fact that it breaks with a conchoidal fracture it lends itself admirably to fabrication by crude methods. The so-called flint paper of commerce is coated with a variety of flint called flint quartz. This mineral is mined extensively in Wisconsin, Maryland and Maine.

FLINT SHOT

Flint shot is a trade name applied by the United States Silica Co. to a product produced by disintegrating Saint Peters rock, a white sandstone, and washing, drying and screening to size the hard flint granules contained in that rock. The grains of this material are very hard without cleavage lines so they do not split and splinter. Thus they can be used over and over again in such operations as sandblasting. This material is used extensively in foundry sandblast rooms for cleaning castings.

GARNET

The following data on garnet were prepared by V. L. Eardley-Wilmot. Garnet is a name given to a certain group of minerals

possessing similar physical properties and crystals forms. The group consists of seven different species, all of which are silicates of either aluminum, calcium, magnesium, iron, manganese, or chromium, the different silicates being replaced, one with another. These varieties are as follows:

Grossularite ($3 \text{ CaO}, \text{Al}_2\text{O}_3, 3 \text{ SiO}_2$); pyrope ($3 \text{ MgO}, \text{Al}_2\text{O}_3, 3 \text{ SiO}_2$); almandite ($3 \text{ FeO}, \text{Al}_2\text{O}_3, 3 \text{ SiO}_2$); spessartite ($3 \text{ MnO}, \text{Al}_2\text{O}_3, 3 \text{ SiO}_2$); andradite ($3 \text{ CaO}, \text{Fe}_2\text{O}_3, 3 \text{ SiO}_2$); uvarovite ($3 \text{ CaO}, \text{Cr}_2\text{O}_3, 3 \text{ SiO}_2$), and rhodolite which is a mixture of two molecules of pyrope to one of almandite.

Many of the species of garnets vary considerably as to color, hardness, toughness and method of fracture. For the best abrasive purposes the mineral must be the hardest possible, at least 7.5. Quartz is 7. When the garnet is crushed the grains should break into sharp angular fragments without curves, flat, or rounded edges. The mineral should be so tough as not to break too easily and so brittle that the individual grains eventually will break and form new cutting edges rather than become rounded under the strain of use.

When used as a coated abrasive long, "slivery" or thin grains do not arrange themselves correctly since they tend to lie too flat, thus presenting a smooth surface, or they protrude above the surrounding grains and tend to scratch. Furthermore, the crushed garnet grains should have a high capillary attraction in order that the glue will completely cover and adhere to them when they are being coated on to the paper or cloth. The color does not seem to have any particular bearing on the abrasive qualities, but the deep red-colored mineral is always preferred. This may be due to prejudice, since the Spanish garnet is of a pale pink color and is of inferior quality.

The garnet should allow of being broken into comparatively large, clean and solid, pea size pieces, a minimum amount of fines so that the full ranges of grades necessary for coated papers can be obtained, and, therefore, deposits that contain garnets of very small crystals are of little or no commercial value, no matter how great the garnet content of the rock may be. Granular garnet usually breaks into rounded grains; other deposits containing large crystals which are badly shattered would, with little pressure, crumble almost to dust.

The grains in garnet sands are not only too small but are

also rounded by erosion and water action. Among the common types of deposits, those containing clean unfractured individual red crystals, at least the size of a pea, but preferably larger, should be suitable for abrasive purposes and the ore should contain at least 10 per cent garnet in order to be commercially valuable. The solid, hard and compact, massive garnet might be used commercially, but comparatively little experimental work has been done on this type. Up to the present the highest grade abrasive material has been obtained from the large laminated crystals or boulders of red garnet such as occur in New York state.

Almandite is by far the commonest of the garnets and is the type most employed for abrasive purposes, although andradite and rhodolite are also being used. They are all iron garnets.

Over 90 per cent of the garnet mined is used for the manufacture of garnet-coated paper and cloth and the remainder as a lower-priced material in the form of loose grain for various purposes such as for surfacing and polishing marble, slate, soapstone and other soft stones; in some sandblast operations, and for the surfacing of plate glass.

On the American continent garnet-coated papers and cloths are used, almost to the exclusion of all other forms of abrasives, in the woodworking industries, particularly for sanding hard woods. In abrading soft woods garnet and quartz papers appear to be nearly equally efficient since both are soon clogged with the wood particles; consequently there is no advantage in the higher price garnet. The recent introduction of open-coated papers, however, largely overcomes this trouble. In hard woods the superiority of garnet over quartz is most pronounced and the cutting of the former is said to be from two to six times that of the latter.

These papers are also used for the finishing of hard rubber and celluloid, also on felt and silk hats, and as fine abrasive disks in dental work. They are employed quite extensively on leather, particularly in the boot and shoe industry for the scouring of heels and soles. In recent years fine grits of waterproof garnet papers have taken the place of pumice in the rubbing down of varnished and painted surfaces, especially for automobile bodies. Garnet cloth is sometimes used for the softer metals such as brass and copper. The garnet-coated abrasive

is used in the form of belts, covers for drums, disks and as small sheets in hand work. The different grades of garnet used on these papers and cloths range from No. 5, the coarsest which is about 15 mesh, to 7/0 which is about 220 mesh. There are about a dozen manufacturers of abrasive-coated paper in the United States, and two in Canada.

The largest use for garnet in the form of loose grains is for the surfacing of plate glass, and in the United States several plate glass manufacturers are now using crude water-graded garnet in the "fining" process between the sanding and final rough polishing operations.

Even a small amount of garnet grain is bonded into wheels for use in glass and some metal grinding. The silicate or shellac processes of manufacture are used, since the low fusion point of garnet, 1300 degrees Cent. and its alteration by heat, renders it impossible to make garnet into wheels by the vitrified process.

Garnet has been used with some success for the surfacing of the softer ornamental stones, also as a substitute for sand in sandblasting operations; and as the abrasive used with gang saws for cutting stone, but these uses are still in the experimental stage.

In Europe garnet is not employed so extensively as on the American continent, although its use is increasing. This may be attributed to the high price of garnet and to the use of chalk flint, which is cheaper and occurs in great abundance in England and France. It is superior to the American flint or quartz and almost equal to garnet in its abrasive qualities. The annual consumption of garnet in England probably does not exceed 2000 tons per year.

Garnet was first employed as an abrasive in United States and became commercially important about 1880, when it was used as a coated abrasive by Herman Behr & Co., and its superiority over flint and the Californian red carnelian for sanding hardwood was quickly established. The first mining operations were conducted by H. H. Barton in the Adirondack section of New York state, followed immediately afterwards by the development of a deposit by Herman Behr at Boothwyn, Delaware county, Pennsylvania, and later, of deposits in Connecticut. The first large-scale milling of garnet ores was done by F. C. Hooper of the North River Gar-

net Co. in 1893. After the exhaustion of the Pennsylvania and Connecticut deposits, production was confined to New York, New Hampshire, and North Carolina. The New York mines are now the world's leading producers.

For many years garnet has been produced from Spain, but is of inferior quality to the American and was never a serious competitor, except in the early days of the industry, and the present output of Spanish garnet is almost negligible.

There is no efficient method of testing the abrasive quality of garnet or of any other loose grain abrasive. The real test is in its practical application. There are, however, several rough tests and examinations which serve to indicate their abrasive possibilities.

The garnets in the original ore should be so large and pure that when crushed and screened they will yield a full range of grades from 20 to 200 mesh, particularly the former. Garnets smaller than pea size will make too many fines.

A microscopic examination of the small broken particles of garnet, will show whether the fracture is clean, sharp, angular, rounded, "slivery," etc. Grains exhibiting rounded or blunt edges are not likely to be of any abrasive use. In some garnets the individual grains tend to show fractures and have a "sugary" appearance under the microscope. These will break too easily when applied to the work. The term "granular" fracture has been applied to this phase.

This kind of fracturing is in most cases due to weathering and the mineral should not be condemned until a fresh sample has been examined. Long "slivery," or flat-sided grains are a disadvantage, as they tend to present a flat surface when applied to the cloth or paper, or they may stick up above the other grains and be more easily torn away.

The microscope may reveal minute embedded impurities which are liable to affect the toughness and abrasive quality.

A variety of garnets can be roughly compared for toughness by reducing them to the small grade, No. 1, and drawing a knife blade over a small quantity placed on a piece of steel or glass. Soft garnets will drag and soon break up into powder, while the knife will ride over the particles of a tough garnet without appreciably reducing their sizes. With a little practice

a close approximation can be reached by comparing with a known standard tough garnet.

The capillary test depends on the capillarity of crushed garnet and serves to indicate its tenacity when applied to the glued surfaces of the paper or cloth. The higher the capillarity the tighter will each particle adhere when coated with glue. In making comparison care should be taken that the grains are of the same mesh and are absolutely dry, clean and free from dust. The apparatus simply consists of a glass tube about 10 inches long, 4 or 5 millimeters inside diameter, and blocked at one end by a piece of fine screen. The tube, which should be dry and clean, is partly filled with the sample to be tested, gently shaken down and the closed end dipped into a known height of water, about $\frac{1}{2}$ inch. The water will rise up through the screen and into the garnet, and after 3 or 4 minutes the tube may be removed from the water and the dry garnet poured out. The remainder, which adheres to the inside of the tube, is measured. The height of water into which it was placed should be deducted.

Although color has nothing to do with the abrasive quality garnets of a deep red color are preferred, and it is a noticeable fact that the fracture and toughness of the brown and yellow shades are not so good as those of the red and pink varieties.

In recent years the utilization of very fine grades of garnet has found favor for the surfacing of plate glass. This material is now used by a few glass firms in the United States and may eventually be used by the European manufacturers.

The preparation of the material used by one firm is as follows:

The crude ore which averages 35 to 40 per cent garnet in pea-size crystals is crushed at the glass plant in a jaw crusher. The product is then hand fed into a small Hardinge ball mill using $\frac{1}{2}$ to 1-inch chrome steel balls and is pulverized to a very fine pulp which is then pumped up to a series of 10 settling-tanks. These tanks are 14 inches deep but widen out horizontally in the shape of a fan so that each tank is larger than the preceding one, thus retarding the rate of flow of the solution. The pulp from the ball mill is fed through a $\frac{1}{8}$ -inch pipe alongside of which water at about 24 gallons per minute is added. The settlings from the first six tanks are sent back to the

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ball mill for regrinding and are thus in closed circuit. The settlings from the next four—Nos. 7 to 10 fall into 4 agitation tanks from which they are pumped to the glass surfacing machines, each grade being fed to its own set of polishers. The grain sizes of the four grades used are all 300-mesh and are theoretically as follows: No. 7—0.001; No. 8—0.0009; No. 9—0.0008; No. 10—0.0007 inch.

It will be seen from the above that the crude ore is used without any concentration though the overflow from the last tank will eliminate an appreciable amount of the lighter minerals such as quartz, mica, feldspar, etc. The garnet is used in the intermediate stage of the surfacing of the glass between the coarser sand and the final rouge.

Prepared garnet ready for the glass trade is not on the market and it is doubtful in what state the garnet should be. Possibly a fairly high-grade concentrate of about 150 mesh which would then be ground and graded at the glass plant might be preferable. A pure garnet may be found to be too harsh, so that the softer impurities, such as are present in the ore, would tend to tone down the scratches and would be comparable to the use of fine emery rather than flour carborundum in certain metal polishing operations. The finer concentrates or middlings from the garnet mills which are not marketable for the coated trade, might be worked up and utilized for glass surfacing.

LIME

Lime as used for buffing is freshly calcined limestone, high in magnesia content. It consists of oxides of calcium and magnesium. The grains of the material are softer than amorphous silica (diamotaceous earth) but somewhat similar in structure being free from sharp edges. Lime will slack on exposure to air so that lime compositions are mixed with a binder and poured into tin containers which are sealed to be opened only when ready for use. Lime compositions are used extensively for buffing nickel plate and other high finishing operations.

METALLIC ABRASIVES

Metallic abrasives are both steel and iron, made in various forms for different abrasive purposes. The products of the

Globe Steel Abrasive Co. are called high carbon chilled shot and cornered steel grit.

The large sizes of the chilled shot, such as Nos. 00, 1C and 1 are used for burnishing and polishing purposes. Nos. 2, 2½ and 3C are used in core drilling operations in testing lands for minerals. They also are used for drilling cores from concrete highways for testing purposes, to ascertain if roads have been laid according to specifications. Nos. 2, 2½ and 3C chilled shot also are used in the granite industry for sawing stone. Nos. 3, 3½ and 12 are used also for grinding and polishing granite, sawing limestone, brownstone and similar materials. Finer sizes of the chilled shot are used for sandblasting in cleaning castings, forgings, etc. All sizes of the cornered steel grit are used for sandblasting castings, etc., and some of the larger sizes of this material also are used for sawing stone.

The products of the Pittsburgh Crushed Steel Co. are called diamond crushed steel and angular grit.

The former material is crucible steel specially treated and crushed and graded into sizes of 4, 6, 8, 10, 12, 14, 16, 18, 20, 30, 36, 40, 50, 60, 70, 90, 120, 150, 170, 190 and 200. Material from six sizes, 60 to 200 is called steel emery. This product is used for grinding various kinds of stone. Angular grit is a crushed iron product used principally for sandblasting. It is crushed chilled iron prepared in sizes of 10, 12, 20, 30, 40, 60, and 90.

The product of the Steel Shot & Grit Co. is called Samson steel shot. It is used for various purposes for such as sawing, polishing, rubbing, etc., on stone work. Finer sizes are used for sandblasting. This company also markets a material called diamond steel grit which is made in about 10 sizes. It is used in the granite and stone industry for the same purposes as the shot is used. The greater part of the output, however, is used for sandblasting.

The American Steel Abrasives Co. grades its steel shot according to a standard wire gage and its steel grit by standard meshes as follows:

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Steel Wire Gage No.	Shot Sizes		Standard Mesh No.	Grit Sizes		American Eversharp Grit No.
	Diameter of Wire and Shot	American Standard- ized Steel Shot No.		Size of Mesh Wire	Size of Mesh Opening	
10	.135	10	8	.032	.093	8
11	.120	11				
12	.105	12	10	.025	.075	10
13	.092	13				
14	.080	14	12	.025	.058	12
15	.072	15				
16	.0625	16	14	.017	.054	14
17	.054	17				
19	.041	19	18	.015	.0406	18
20	.035	20	38	.0085	.0178	38
22	.0286	22				
25	.020	25	45	.0095	.0127	45
28	.016	28				
30	.014	30	70	.0065	.0078	70

PULP STONES

The large stones used for grinding wood pulp in the paper making industry are a selected variety of sandstone or artificial abrasive wheels. Large quantities of these stones are used in this country and abroad. The natural variety is found principally in Ohio. Considerable success years ago was had in the adaptation of artificial abrasive wheels to this work in Norway and Sweden. For many years, however, these wheels met with little or no success in this country, due probably to the low cost and success of the natural material. Recently, however, successful pulp wheels of artificial abrasives have been perfected in this country. They are made in sections and held securely over an iron center. The crevices between the sections are filled with soft metal of the nature of babbitt. The sectional wheels are 54 inches in diameter, 27-inch face, 30 grit. They can be operated at 450 revolutions per minute.

PUMICE

In this country pumice is found in California, Kansas, Nebraska, Idaho, South Dakota and Utah while the principal source of the foreign material is the isles of the Mediterranean Sea. Pumice is of volcanic origin, being an igneous rock of an amorphous nature. It often contains impurities such as feldspar and hornblende.

Primitive methods are followed in mining foreign pumice. The workings are on mountain sides, often in deep caves. The

material is gotten out in lump form and transported down the mountain side on donkeys. Here it is sorted and graded carefully by women who become expert through experience. Three kinds of pumice are known to the trade as American, Italian and Italian American ground. It is said that the material is ground more carefully in this country than abroad.

Pumice is used as an abrasive for a diversity of purposes. It is used in the automobile body finishing industry in the form of hone gangs for rubbing down *rough stuff* on automobile bodies. In powder form it also is used with water for rubbing paint and varnish.

PUMICE COMPOSITION

A composition made of powdered pumice mixed with a suitable binder and furnished in cake form. It is used on brush wheels for producing a brush brass effect. Also it is used for cutting down hard rubber and similar substances.

PUTTY POWDER

Putty powder is oxidized tin, burnt with a certain amount of lead litharge. The value of this material is that it imparts a permanent polish on cut glass, marble, granite, etc.

QUARTZ

A well known and common material composed of silicon dioxide or silica, SiO_2 , and found the world over. It has a specific gravity of 2.65 and a hardness of 7 on Moh's scale. This material crystallizes in the trapezohedral-hemihedral class of the rhombohedral division of the hexagon system. Pure quartz forms many semi-precious stones such as the blood-stone, amethyst, sardonyx, etc. Quartz is a valuable abrasive for many purposes. In grain form it is used for grinding plate glass and glued on belts it makes an excellent medium for sanding handles. It also is employed for sandblasting, stone sawing, etc. It is not an efficient abrasive for grinding wheel manufacture, but it sometimes is employed in wheel mixtures in small quantities for specific reasons, such as making an open cutting wheel for knife grinding.

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ROUGE COMPOSITION

A material composed of rouge mixed with a suitable binder and molded in cake form. It is used for buffing gold, silver, platinum and also for fine finishing on glass, brass, nickel steel, etc. This material was one of the first buffing compounds to be used.

ROUGE AND CROCUS

These are manufactured abrasives, although this fact is not generally known. Both are made by a similar process, that is the calcining of sulphate of iron in crystal form. The material is placed in crucibles and subjected to a high temperature. The resultant powder that forms at the bottom of the mass is crocus; that at the top rouge. True rouge is red, while crocus is purple. Cloth coated with rouge, however, often is called crocus cloth. Both rouge and crocus are used in buffing and polishing operations, for instance, in the color buffing of brass. Large quantities of rouge are used in polishing plate glass, lenses, etc.

SANDSTONE

A natural abrasive found abundantly in many parts of the world chiefly in the United States. Sandstone is the oldest natural abrasive known. It is a sedimentary rock formed of small grains of silica or quartz firmly cemented together with silica. The material is quarried out by open-cut methods, graded and selected and formed into grindstones for various purposes. Pulpstones as used for grinding wood pulp for paper making also are a variety of sandstone and this branch of the grindstone business is probably the most important today, due to the fact that natural sandstones are being replaced gradually by abrasive wheels.

SHARPENING STONES

A general name given to any stone natural or artificial to be used by hand. Natural stones are made of various substances such as sandstone, silica, etc. They include axe stones, scythe stones, carpenters stones, etc., and no end of stones for various purposes. Scythe stones are sandstone while Arkansas and Washitsa stones as used by carpenters and cabinetmakers, engravers, etc., are over 90 per cent silica.

Manufactured abrasive stones are made by the same methods employed in grinding wheel production. The finished stones as they come from the vitrifying kilns are rubbed on circular cast iron revolving beds to smooth their surfaces. Such goods are very attractive and command a ready sale, especially razor hones. Both carbide of silicon and aluminum oxide are used in the manufacture of artificial stones.

SPANISH MINERAL

Spanish mineral is a trade name given to a certain variety of garnet grain mined in Spain. At one time this abrasive enjoyed an extensive sale in this country. No analyses are on record to establish the composition of this material, but the United States Geological survey states that it probably is a form of iron-alumina garnet.

STEEL WOOL

Steel wool, according to Herbert R. Simonds, originally was a by-product in the manufacture of loom heddles but it now is produced on a commercial basis by several types of machines. The product, which merely consists of long steel shavings or fibers, finds wide application as an abrasive or polishing medium as a substitute for emery cloth, sand paper or pumice stone for cleaning hollow ware, rheostats, patterns, tools, windows, brass sign plates, railings, machine parts, enameled ware, cooking utensils, bathroom fixtures, mirrors, cut glass and for removing paint from marble, tile, glass and porcelain. Large quantities also are consumed by shipbuilding companies, furniture and woodworking factories and in the household. In japanning work any drips, runs or other defects are smoothed out by steel wool with the result that after the second dip no scratches are visible.

Prior to the war large quantities of steel wool were imported in various sizes and degrees of fineness from Switzerland and Germany but since then production in this country has increased to the point where the yearly output approximates 1,400,000 pounds. The product, which is triangular in cross section, is made in several grades from coarse fibers to wool so that any kind of cleaning and polishing can be accomplished and is packed in small, medium and large cartons which retail at 40 cents per pound.

Certain American manufacturers produce steel wool from high-manganese bessemer wire by attaching one end to a power-driven drum. The wire is pulled under several knife blades of the saw tooth type arranged in tandem in an inclined position similar to a bit in a hand plane. Triangular shaped slivers of steel are shaved from the wire and when about seven-eighths of the wire is converted into steel wool the residue becomes too thin to withstand the pulling strain and is discarded. In later type machines the wool is produced by drawing the wire through circular cutting dies. Foreign made steel wool is produced by first shaving a thin fiber from soft steel wire in order to present a flat surface to the cutting tool. The wire then is stretched over a frame but beneath the cutting tool in such a way that the wire is shredded into filaments of triangular shape cross section. This shape renders the wool sharp for abrasive purposes.

TRIPOLI

Some confusion exists in technical literature, particularly in the abrasive consuming trades as to the correct use of the terms tripoli, tripolite diatomaceous earth (infusorial earth) and *kieselguhr*, according to Raymond B. Ladoo. These terms often are used synonymously by users of grinding materials and even in mineralogies and other reference books. Actually, tripoli is a material of definite and distinct physical and chemical properties, and the other terms belong to a different material which possesses definite and distinct characteristics. Tripoli is used extensively as a mild abrasive material for polishing, buffing and burnishing.

Originally the term tripolite (loosely called tripoli) was given to a diatomaceous earth from Tripoli in northern Africa. J. S. Dana in *A System of Mineralogy*, calls this material tripolite and gives no authority for the use of the term tripoli. Between 1880 and 1890 the deposits near Seneca, Mo., were opened and the material placed on the market as tripoli, no doubt due to its resemblance in some respects to the original tripolite or diatomaceous earth from Tripoli. Since that time the term tripoli, with increasing definiteness, has been reserved for the Seneca material and other siliceous material of similar origin and physical properties, while all siliceous material of organic origin, containing diatoms, has

been called diatomaceous earth or by its synonyms, infusorial earth, *kieselguhr*, etc. Rottenstone is sometimes classed with tripoli.

Tripoli, when pure, is a white, finely granular, very porous, siliceous rock usually derived from the decomposition or alteration of chert, but sometimes derived, as a residual product, from the decomposition of siliceous limestone. It is loosely coherent and may thus be crumbled easily in the hand, but its individual grains are so hard that they will scratch steel. Individual grains have been measured by Hovey, who found that the majority of the particles were less than 0.0004-inch in diameter, although occasional grains were as large as 0.0012-inch. The grains are double-refracting.

In contrast with tripoli, diatomaceous earth is a soft, white, porous rock composed of the siliceous skeletons of small aquatic plants called diatoms. There are a very large number of types and varieties of diatoms, over 4000 distinct forms having been noted and described. These may vary in size from as large as the head of a pin to such minute proportions as to be distinguished only with the aid of the highest powered microscope. They are always present and form a means of absolute identification of diatomaceous earth. The silica is in the amorphous or opaline state and carries 5 to 10 per cent of chemically combined water.

The true specific gravity of diatomaceous earth is 2.1 to 2.2 but the apparent specific gravity is as low as 0.45 for dried blocks, due to the high porosity. Diatomaceous shale, a harder and more compact form, has a higher apparent specific gravity. Typical analyses of tripoli and of diatomaceous earth illustrate the differences in chemical nature of the silica present in each and are given in the accompanying table.

It should be noted that a theoretically pure tripoli should contain 100 per cent silica while a theoretically pure diatomaceous earth should contain less than 95 per cent silica and five per cent or more of chemically combined water. Tripoli may be distinguished from diatomaceous earth by the following tests:

1—Pure, dry diatomaceous earth usually has an apparent specific gravity of less than 1, that is, it will float on water. Tripoli usually is heavier than water and thus will not float.

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2—Under a high power microscope tripoli appears as more or less rounded grains, while diatomaceous earth shows diatoms of a peculiar shell-like structure. Tests should be made on finely pulverized material moistened with water, on a glass slide.

3—The analysis of a pure white tripoli will usually show over 95 per cent silica while a pure white, light weight, diatomaceous earth will usually show less than 90 per cent silica. Another difference which may have an important bearing upon utilization is that the individual grains of tripoli are solid, while the grains of diatomaceous earth are hollow or contain hollow pore spaces.

The following are typical analyses of tripoli from Seneca, Mo., and diatomaceous earth from Lompoc, Calif.:

	Tripoli, Seneca, Mo. per cent	Diatomaceous earth, Lompoc, Cal. per cent
Silica, SiO_2	98.28	88.78
Alumina, Al_2O_3	0.17	2.68
Iron oxide, Fe_2O_3	0.53	trace
Lime, CaO	trace	1.61
Potash, K_2O	0.17	.....
Soda, Na_2O	0.27	.....
Magnesia, MgO} .....	.....	1.30
Titanium oxide, TiO_2 .....	.....	0.10
Water, H_2O	0.50	5.54
Total	99.92	100.01

Pure tripoli is a white rock varying from rather crumbly to fairly compact in structure. In some deposits iron-bearing surface waters have entered the tripoli through cracks and stained part of the material a yellow, pink or reddish color. Fortunately there is a demand for this colored material and none of it need be wasted. Tripoli when dry is highly absorbent. It is claimed that a block four inches square will absorb one-third of its weight of water (complete saturation) in five minutes. This moisture will dry at ordinary room temperature and humidity in about three days. In small pieces the fracture is uneven, but in large blocks in the quarry a tendency toward concentric or conchoidal fracture is often found. Some beds, in the Missouri-Oklahoma district, are of sufficiently compact material so that large, fairly strong blocks may be removed.

The productive tripoli deposits, centered about Seneca, Mo., on the Missouri-Oklahoma boundary line, are scattered over an area of less than 100 square miles. The quarries of the American Tripoli Co. are being worked actively. They are about $1\frac{1}{2}$ miles north of Seneca, partly in Missouri and partly in Oklahoma. The beds of tripoli always lie horizontal and never have more than 12 feet of overburden. This overburden, consisting of loose dirt, gravel and decomposed tripoli, averages about five feet thick. The beds range from 2 to 20 feet in thickness with a possible average of 12 to 14 feet. While the beds are apparently extensive, often chert seams and boulders occur in such abundance that grinding would be uneconomical. A weight of one short ton per cubic yard in place is used in estimating ore reserves.

WHITE ROUGE

This expression really is a misnomer. It is applied to soft silica compounds used for color buffing. Its use is preceded by a tripoli composition or fine emery cake. Sometimes the surface to be colored does not require the preliminary treatment.

SECTION II

ABRASIVE PAPER AND CLOTH

The term abrasive paper and cloth is a general one used to designate any abrasive material coated on a flexible or semiflexible backing. Such materials also are called coated abrasives. Enormous quantities of these products are used in the woodworking, metal finishing and other industries. The subjects treated in this section are arranged as follows:

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ABRASIVE PAPER AND CLOTH

ABRASIVE BELTS

Abrasive belts are used for finishing metal, wood and other nonmetallic surfaces. As a rule belts for finishing metal are coated on a cloth backing, either jeans or drills, while paper backed belts can be used for finishing wood or other nonmetallic surfaces. However, a cloth backing is to be preferred in any case where the strain on the material is excessive. Another form of backing, called a combination backing, composed of paper and a light web of cloth, often is used; especially for making garnet-cloth belts.

Abrasive belts can be coated with any of the common abrasive materials such as emery, corundum, flint, garnet, aluminum oxide or carbide of silicon. As a rule carbide of silicon is used for finishing cast iron, brass and other materials of low tensile strength. Alumina, either natural or manufactured, is used for finishing steel. Flint and garnet are used for wood working. In determining the best abrasive to employ for belt grinding other nonmetallic materials, experimentation often is necessary.

As but few variables are present it is a simple matter to test belts made of various materials. As a rule carbide of silicon can be relied on to finish such substances as glass, porcelain and other ceramic products, hard rubber, fiber, etc. Garnet and flint will show the best results for wood working.

The speed of an abrasive belt is determined by the ability of the bonding material to stand up under the heat generated. If the belt is operated at an excessive speed the bond will soften. In the case of woodworking, an excessive speed will burn the work. A safe speed for both metal and other substances is 1500 feet per minute. This speed can be increased under certain conditions but the tests should be made judiciously.

Great care should be exercised in making the belt joint. It can be made at an angle across the belt face. Some operators prefer to skive down each edge so as to make a joint of uniform thickness. This practice is to be recommended. Then the ends are glued or cemented together and a thin strip of paper or cheese cloth pasted over each side of the joint. The joint should be dried under pressure. Another method consists of using a special die which cuts a series of scallops on each end of the belt. These fit together forming a compact joint.

ABRASIVE PAPER AND CLOTH

Abrasive-belt machines are of various kinds. Those used in woodworking establishments are termed belt sanders, while the term belt grinder generally is applied to the machines used for finishing metal surfaces. These machines are made by several manufacturers, but they all employ the principle of driving the belt over two pulleys. Idler pulleys sometimes are employed. In some belt-sanding machines, the belt runs abrasive side downward where it is pressed against the work by a manually or mechanically operated pad. In other instances, especially in metal working, the belt runs abrasive side upward. The vertical type machine also is employed for various purposes.

ABRASIVE PAPER AND CLOTH MANUFACTURE

Abrasive paper and cloth is made on a special machine technically termed a "making machine." The process briefly described is as follows:

The web of paper or cloth traveling at a uniform speed first passes through a rotary printing press that imprints the grit number, trade mark, etc., at regular intervals. Then the web of paper is spread thoroughly with a high grade of glue. The paper with the glue coating next passes under a hopper from which a regulated flow of abrasive falls. Next in its journey the material is given a sizing coat of glue. Then by mechanical means it is hung up in festoons to dry in the same manner that wall paper is dried. Then it is wound in large rolls and set away to age as the so-called "green" paper is not an efficient product. After curing thoroughly, which should consume several weeks, the paper is cut into the desired widths and wound in rolls or cut into sheets for ream goods. Various weights of backing are employed for specific purposes. The machinery used by abrasive paper and cloth manufacturers all is of a special nature, each company designing and building its own equipment. However, the drying apparatus can be supplied by manufacturers who make equipment for wall paper making.

COATED ABRASIVES

A term applied to any abrasive material coated on a cloth or other backing and furnished in sheets, rolls or disks. Commonly used coated abrasives are flint paper and cloth, garnet paper and cloth, emery paper and cloth, aluminum oxide paper and cloth, carbide of silicon paper and cloth and crocus paper

and cloth. The foregoing materials, with the exception of crocus, are made also in disks. Aside from the paper and cloth backings, a combination backing made of paper and a thin web of cloth also is used in making materials for belt sanding.

The paper backing of coated abrasives is substantial rope paper stock. It is made in various weights for specific purposes. Cloth backing is light or heavy duck, called jeans and drills. The so-called waterproof paper is used for rubbing paint. It is made waterproof so that it can be used with water or oil. Coated abrasives are made both close and open coated. The open form of coating is comparatively a new departure. Such papers are used for sanding paint or varnish or for any purpose where ordinary close-coated paper shows a tendency to fill up readily.

Flint paper is furnished in the following grits: 4/0, 3/0, 2/0, 0, 1/2, 1, 1 1/2, 2, 2 1/2, 3, 3 1/2, 4. Sheets are 9 x 11 or 8 3/4 x 10 1/2 inches. The so-called finishing paper, both single and double face, is furnished in grits from 5/0 to 1 in 9 x 11 sheets. This material also is furnished in rolls 11 inches wide and 60 yards long. Regular flint roll paper is furnished in grits from 3/0 to 3 1/2 in rolls from 2 1/2 to 48 inches wide and 50 yards long. Flint roll cloth is not made over 28 inches wide. Flint paper disks are made in all grits from 3/0 to 3 1/2 in diameters ranging from 6 to 48 inches. Flint cloth disks, however, seldom are furnished in diameters above 28 inches.

Garnet paper is furnished in all grits from 4/0 to 3 1/2 in 9 x 11-inch sheets. Single-face garnet finishing paper is furnished in grits from 7/0 to 0 in 9 x 11-inch sheets, while the double face material also can be had in 11-inch rolls 60 yards long. Garnet roll paper comes in widths from 2 1/2 to 48 inches in grits from 3/0 to 3 1/2, in 50 yard rolls.

Garnet paper disks are made in sizes from 6 to 48 inches in diameter in grits from 3/0 to 3 1/2. Garnet cloth comes in 50-yard rolls from 2 1/2 to 28 inches wide in grits from 3/0 to 3 1/2. Garnet cloth disks are made in diameters from 6 to 28 inches in grits from 3/0 to 3 1/2. Garnet combination (paper and cloth backing) comes in rolls from 2 1/2 to 28 inches wide, 50 yards long. Garnet combination disks are made in diameters from 6 to 24 inches in grits from 3/0 to 3 1/2.

Emery cloth is made in 9 x 11-inch sheets in all grits from 3/0 to 3 1/2. Crocus cloth also is furnished in 9 x 11-inch sheets.

ABRASIVE PAPER AND CLOTH

Emery cloth is also made in 50-yard rolls in grits from 3/0 to 3 1/2 in widths from 3 to 27 inches. Special narrow rolls for general workshop use come in sizes from 1/4 to 2 1/2 inches. Emery-cloth disks are made in grits from 3/0 to 3 1/2 in diameters from 6 to 27 inches. Emery paper comes in 9 x 11-inch sheets in all grits from 3/0 to 3 1/2. Emery-paper rolls are 50 yards long in grits from 3/0 to 3 1/2 in widths from 4 to 24 inches. Emery-paper disks come in grits from 6 to 24 inches 3/0 to 3 1/2 in diameters from 6 to 24 inches. When manufactured abrasives are used in place of emery cloth, the package sizes and grit numbers generally are the same.

Flint paper and cloth are used for a diversity of sanding operations on comparatively soft wood. Flint paper, however, also is distinctly a household article. Enormous quantities of it are sold by the sheet over hardware-store counters every day. It also is used extensively for rubbing down paint.

Garnet paper and cloth are used for sanding hard woods in the furniture manufacturing and allied industries. Garnet finishing paper is used for rubbing varnish. The price of garnet sheet paper makes it prohibitive as a household article, although its cutting qualities are far ahead of those of flint paper.

Emery cloth is used the world over in machine shops for polishing cast iron, steel brass, etc. Large quantities of emery cloth also are used by every navy for keeping guns and other steel work bright. Emery paper is used in preference to emery cloth where a very light backing is required or where a backing less substantial than cloth will stand up to the work.

Aluminum oxide paper and cloth, which is sold under no end of trade names, is used to take the place of emery. It is a very fast cutting material and much in demand.

Carbide of silicon paper and cloth is used chiefly in the boot and shoe and other leather working industries, taking the place of the garnet paper and cloth heretofore used. Carbide of silicon paper also is an excellent medium for rubbing paint and varnish and large quantities of it are used for this purpose.

Increase in the use of abrasive belt machines for metal finishing has furthered the use of coated abrasives to a great extent. The materials are used in the form of cloth belts. Carbide of silicon is used for finishing cast iron, brass, etc., while aluminum oxide is employed for steel finishing.

EMERY CLOTH FILLETING

A trade name for a special abrasive used in card clothing grinding which consists of a narrow band of strong linen backing, from 1 to 1 1/2 inches wide, coated with emery grain. This material is made in England exclusively. The grits used range from No. 4 to 40. After the grain is applied to the fillet the surface is grooved, the grooves being as near as possible the same width as the emery grains. Thus a saw-tooth surface is imparted which permits a clearance space. This material is wound spirally on a *dead-roll* grinder, an appliance for grinding card clothing.

HAT FINISHING

A variety of abrasive paper called pouncing paper has been in use for over 75 years for the finishing of felt hats. Felt used in hat manufacture is called fur felt. It is made from the hair of rabbits, musk-rats, beavers and like animals. Felt is not woven, but composed of loose fur which naturally interweaves as the forming or shrinking process is carried out. When the pouncing paper first is applied the hat is a crude shaped, hairy cone with stock enough at the large end to form the brim. The hat is drawn tightly over a wood form and the crown is *pounded* or smoothed with pouncing paper as it rotates rapidly. The abrasive cuts away projecting hairs. The next operation on soft hats (fedoras) consists of pouncing the brim by passing it between rollers one of which is covered with pouncing paper in a coarse grit. Sometimes oscillating paper pads are employed instead. They are mounted on a *brim jigger* machine. For finishing stiff hats (derbies) the operations differ somewhat, but the principle is the same. A number of operations on the hat are performed between pouncing and finishing which is the next abrasive step. In the finishing room the hat receives its final form as it is blocked into shape. The surface is further pounded with fine grit paper.

METAL SANDING

A term applied somewhat loosely to the use of coated abrasive materials for smoothing metallic surfaces. Large quantities of abrasive materials are used for rubbing down metal automobile bodies before the initial application of paint. This work formerly was performed by hand, but present-day practice

ABRASIVE PAPER AND CLOTH

leans toward the use of special hand appliances for rotating disks of abrasive material. The term metal sanding also is applied to the finishing of metallic surfaces on belt grinding machines.

OIL SANDING

A term applied to a process followed in rubbing down automobile bodies. It consists of soaking the abrasive paper in oil before it is used. This process is being superseded to some extent by the use of waterproof abrasive paper.

OPEN-COAT ABRASIVE PAPER

A name applied to a special kind of abrasive paper for use in rubbing down paint on automobile bodies. As its name implies, the coating is open, that is space is allowed between the abrasive grains so that the material will not fill or clog readily.

POUNCING PAPER

Pouncing paper is a coated abrasive product used in the manufacture of felt hats. The abrasive medium is finely powdered pumice. The name is a contraction of the French term, *papier de ponce*, which literally means pumice paper. Hats were originally finished with pumice. In the felt-hat industry the paper is applied to the hat as it revolves on a spindle to remove projecting fibers, leaving a smooth nap. Pouncing paper is produced by two manufacturers only, both located in the United States. Pouncing paper grits from coarse to fine are as follows: D, C, B, A, 0/A, 00/A, 000/A, 0000/A, 00000/A, 000000/A, 0000000/A, 00000000/A. The coarsest grade, D, equals No. 1/2 sandpaper in grit, C equals 0 grit and 0000/A equals 7/0 garnet finishing paper. The abrasive is flint quartz.

SANDING PRACTICE

Enormous quantities of abrasive-coated paper are consumed annually in both the wood and metal working trades. Sand paper is an old term that today is applied generally to paper or cloth coated with abrasive. The terms coated abrasives or surface abrasives are better ones. Nine x eleven-inch sheets of cabinet paper are used for hand sanding. Finishing paper is used for rubbing paint and varnish. Roll paper is used on machines. Sand-

ing machines are of several kinds. First there is the ordinary disk sander. Such a machine carries a disk of garnet or other abrasive paper against which the work is fed back and forth. Precision machines of this kind have been devised for use in pattern shops. Belt sanders are used for finishing a diversity of work. Such machines employ a belt of abrasive cloth from one to 12 inches wide running over two pulleys. The belt can be horizontal or vertical. When it is desired to get into formed places, the belt can be depressed into a form by the work. A stroke sander is a belt sander with a block that passes back and forth over the back of the belt to keep it in contact with the work. In some instances a pad is fed back and forth by hand for this purpose. A single drum sander consists of a drum about three feet in diameter covered with carpet or felt over which the abrasive is stretched. Such appliances can be used for a number of purposes. A spindle sander consists of an upright spindle from 1/2 to 6 inches in diameter covered with abrasive paper. It oscillates up and down as it rotates and is used for getting into small places. A 3-drum sander has three drums covered with abrasive paper, coarse, medium and fine. Such machines are of two kinds, roll and endless bed feed. In a roll feed sander, rolls feed the stock under the drums. The endless bed machine has a bed made endless or belt shape. It is provided with rubber feet that grip the work. For sanding irregular surfaces a whip sander is used. This consists of abrasive material in slacked strips which is forced against the work, the strips being held in a revolving head. Another type, called the molding sander is used for finishing such parts as chair rungs, etc. They are mounted and rotated between centers and brought against successive slashed abrasive pads.

SURFACING WOOD FLOORS

Wood floors in apartment houses, dance halls, skating rinks, bowling alleys, etc., are surfaced after laying with special abrasive machines. Such floors, especially those of bowling alleys, dance halls, and skating rinks are resurfaced periodically. The machine employed is simple in design as in reality it is a single drum sander mounted on a truck so that it can be rolled over the surface to be treated. Power is supplied by an electric motor. The feed wire is attached to a light socket or floor plug. The

ABRASIVE PAPER AND CLOTH

abrasives commonly used on floor surfacing machines are garnet paper, garnet combination paper and aluminum oxide cloth. This material is furnished in 50 yard rolls in 12, 14, 18 and 24-inch widths. Operators do not agree as to the best grit of material to use. Some prefer No. 2 1/2 material for roughing and No. 1/2 for finishing. Others use No. 3 for roughing. One company operating a number of surfacing machines uses No. 4 material for roughing down old floors and Nos. 2 and 1 1/2 for finishing pine and maple respectively. When aluminum oxide cloth is used, the grit is about 36. Such material is said to be economical where nail heads are plentiful. The operation of the machine is simple as all that is necessary is to roll it slowly over the floor after the correct cutting adjustment has been made. Some operators change the paper oftener than do others. In general two to three rolls of paper will finish a dance hall 75 feet each way or 5625 square feet. A roll of 12-inch material in one test finished 3000 square feet. If a floor is uneven more material must, of course, be used to make it level. In surfacing parquet floors, No. 2 can be used for roughing and No. 1/2 for finishing. Finer material also is sometimes used.

TESTING ABRASIVE COATED PRODUCTS

The method followed in testing abrasives at the plant of the Manning Abrasive Co., according to their research engineer, James F. Adams, is as follows:

The testing is performed on machines of two types, an abrasive disk and an abrasive belt sander. For testing woodworking abrasives, the belt tester is better adapted to the work. This machine embodies two pulleys, 10 inches in diameter and 5 inches face, one the driver, the other the idler. An endless belt of abrasive paper or cloth is placed over the pulleys, one pulley being adjustable to impart the correct belt tension. This is accomplished by a lever to which weights are suspended. The belt is run at a surface speed of 3000 feet per minute. The test material consists of oak blocks, 7/8 x 1 x 5 inches which are held in a printers' chase. A weighted level device is used to apply the blocks to the belt so that the ends of the blocks are sanded. A test lasts ten minutes and the amount of wood cut away in that time is noted and plotted on a chart in the form

of a curve. The blocks are taken at random from a barreelful, cut from a single plank.

WATERPROOF ABRASIVE PAPER

Abrasive paper is made waterproof by using a specially treated paper backing and waterproof glue for holding the abrasive grain in place. This material is used extensively for rubbing down paint and varnish on automobile bodies.

SECTION III

ABRASIVE PRODUCERS

Abrasive products in various forms are produced by nearly 100 manufacturers in the United States and Canada. The data in this section have been arranged for ready reference. They include manufacturers of abrasive paper and cloth, grinding wheels, grindstones and pulpstones, manufactured abrasives, and natural abrasives in grain form.

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ABRASIVE PRODUCERS

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American Glue Co., Boston, Mass.	Federal Abrasive Works, Inc., Westfield, Mass.
Armour Sand Paper Works, Chicago, Ill.	Gardner Machine Co., (Disks Only) Beloit, Wis.
Baeder Adamson Co., Philadelphia, Pa.	Manning Abrasive Co., Troy, N. Y.
H. H. Barton & Co., Inc., Philadelphia, Pa.	Minnesota Mining & Mfg. Co., St. Paul, Minn.
Herman Behr & Co., Inc., Brooklyn, N. Y.	United States Sand Paper Co., Williamsport, Pa.
Charles H. Besly & Co., (Disks Only) Chicago, Ill.	Wausau Abrasives Co., Wausau, Wis.
Carborundum Co., Niagara Falls, N. Y.	

GRINDING WHEELS

Abrasive Co., Philadelphia, Pa.	Eagle Emery & Corundum Wheel Co., Chicago, Ill.
American Emery Wheel Works, Providence, R. I.	Electric Emery Wheel Co., Newark, N. J.
Bay State Abrasive Products Co., Westboro, Mass.	General Grinding Wheel Co., Philadelphia, Pa.
Blanchard Machine Co., Cambridge, Mass.	Hampden Corundum Wheel Co., Springfield, Mass.
Brantford Grinding Wheel Co., Ltd., Brantford, Ont.	Lion Grinding Wheels, Ltd., Brockville, Ont.
Bridgeport Safety Emery Wheel Co., Bridgeport, Conn.	Macklin Co., Jackson, Mich.
Carborundum Co., Niagara Falls, N. Y.	Manhattan Rubber Mfg. Co., Passaic, N. J.
Chicago Wheel & Mfg. Co., Chicago, Ill.	National Grinding Wheel Co., Inc., Buffalo, N. Y.
Cleveland Abrasive Wheel Co., Cleveland, O.	New York Belting & Packing Co., New York, N. Y.
Commercial Grinding Wheel Co., Inc., Chicago, Ill.	Norton Co., Worcester, Mass. and Hamilton, Ont.
Cortland Grinding Wheel Corp., Chester, Mass.	Pacific Corundum Wheel Co., Everett, Wash.
De Sanno, A. P. & Son, Philadelphia, Pa.	Peninsular Grinding Wheel Co., Detroit, Mich.
Detroit-Star Grinding Wheel Co., Detroit, Mich.	Pittsburgh Grinding Wheel Co., Rochester, Pa.
Dominion Abrasive Wheel Co., Mimico, Ont.	

ABRASIVE PRODUCERS

Precision Grinding Wheel Co., Inc., Philadelphia	Superior Corundum Wheel Co., Waltham, Mass.
Quaker Grinding Wheel Co. Inc., Philadelphia	Vitrified Wheel Co., Westfield, Mass.
Safety Grinding Wheel & Machine Co., Springfield, O.	Waltham Grinding Wheel Co., Waltham, Mass.
A. A. Simonds Dayton Co., Dayton, O.	Westfield Grinding Wheel Co., Westfield, Mass.
Springfield Mfg. Co., Bridgeport, Conn.	White Heat Products Co., West Chester, Pa.
Sterling Grinding Wheel Co., Tiffin, O.	Wolf's New Process Abrasive Wheel Co., Meriden, Conn.

GRINDSTONES AND PULPSTONES

American Rubbing Stone Co., Cincinnati, O. (Rubbing stones only)	A. S. McClintock, Successor, Ohio Buff Sandstone Co., Sherrodsville, O. (Grindstones and pulpstones)
Bracher Co., Belleville, Newark, N. J. (Sharpening Stones)	Marietta Stone Co., Marietta, O. (Grindstones)
Briar Hill Stone Co., Amherst, O. (Grindstones and pulpstones)	Middleburg Stone Co., Elyria, O. (Grindstones)
Cleveland Stone Co., Cleveland, O. (Grindstones, pulpstones and sharp- ening stones)	Ohio Quarries Co., Cleveland, O. (Grindstones)
Constitution Stone Co., Constitution, O. (Grindstones)	Ohio Valley Stone Co., Marietta, O. (Grindstones)
Eureka Stone Co., Marietta, O. (Grindstones)	Smallwood Stone Co., Steubenville, O. (Pulpstones)
Hall Grindstone Co., Constitution, O. (Grindstones)	Union Stone Co., Vincent, O. (Grindstones)
International Pulp Stone Co., Elyria, O. (Pulpstones)	Wallace Co., Port Austin, Mich. (Grindstones)
Lombard & Co., South Boston, Mass. (Grindstones and pulpstones)	

MANUFACTURED ABRASIVES

Aluminum Oxide Abrasive Co., Philadelphia, Pa. and Hamilton, Ont.	Carborundum Co., Niagara Falls, N. Y. and Niagara Falls, Ont.
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Federal Abrasives Co.,
Birmingham, Ala.

General Abrasives Co.,
Niagara Falls, N. Y.

Norton Co.,
Niagara Falls, N. Y.

Carbide of Silicon

Carborundum Co.,
Niagara Falls, N. Y. and Shawen-
egan Falls, Que.

Exolon Co.,
Thorold, Ont., and Blasdell, N. Y.

Federal Abrasives Co.,
Birmingham, Ala.

Norton Co.,
Chippewa, Ont.

Metallic Abrasives

American Steel Abrasives Co.,
Galion, O.

Globe Steel Abrasive Co.,
Mansfield, O.

Pittsburgh Crushed Steel Co.,
Pittsburgh, Pa.

Steel Shot & Grit Co.,
Amesbury, Mass.

NATURAL ABRASIVES IN GRAIN FORM

Abrasive Mining & Mfg. Co.,
Plymouth, Ind.

(Emery)

American Abrasive Co.,
Westfield, Mass.

(Emery and corundum)

American Glue Co.,
Boston, Mass.

(Garnet)

H. H. Barton & Sons Co.,
Philadelphia, Pa.

(Garnet)

Hampden Corundum Wheel Co.,
Springfield, Mass.

(Corundum)

Herman Behr & Co., Inc.,
Brooklyn, N. Y.

(Garnet)

Hamilton Emery & Corundum Co.,
Chester, Mass.

(Emery and corundum)

Hulbert Optical Abrasive Co.,
Tilton, N. H.

(Emery and corundum)

Jackson Emery Mills Co.,
Easton, Pa.

(Emery)

Keystone Emery Mills,
Frankford, Pa.

(Emery)

Lithowhite Silex Co.,
Still River, Conn.

(Silica Sand)

Niagara Emery Mills, Inc.,
New York, N. Y.

(Emery)

Pennsylvania Pulverizing Co.,
Lewiston, Pa.

(Silica sand)

Portage Silica Co.,
Youngstown, O.

(Silica sand)

Smith & Ellis,
Peekskill, N. Y.

(Emery)

Rhodolite Co.,
Le Roy, N. Y.

(Garnet and corundum)

Warren County Garnet Mills, Inc.,
Riparus, N. Y.

(Garnet)

Wausau Abrasives Co.,
Wausau, Wis.

(Flint and garnet)

SECTION IV

CYLINDRICAL GRINDING

The art of cylindrical grinding is being reduced rapidly to an exact science as great strides in this direction have been made during the past decade. The majority of cylindrical grinders are of the so-called plain type as used on production operations. Large numbers of centerless grinding machines also are in use, and this important branch of abrasive work has received great attention during the past ten years. The universal grinder is used extensively also; not only on toolroom work, but on certain production operations where it is necessary to have a general-purpose machine. Following are a number of pertinent factors pertaining to cylindrical grinding:

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CYLINDRICAL GRINDING

ALLOWANCES FOR CYLINDRICAL GRINDING

The accompanying table gives grinding allowances that can be applied under ordinary conditions to production work on cylindrical grinders.

Diameter of work inches	Work Length in Inches						
	3	4	6	8	9	10	12
$\frac{1}{4}$	0.007	0.008	0.009	.....	.....	.....	.....
$\frac{3}{8}$	0.008	0.008	0.010	0.012	.....	0.013	.....
$\frac{1}{2}$	0.009	0.009	0.011	0.012	0.012	0.013	0.013
$\frac{3}{4}$	0.009	0.009	0.011	0.013	0.013	0.014	0.015
1	0.010	0.010	0.012	0.013	0.013	0.014	0.015
$1\frac{1}{4}$	0.010	0.011	0.012	0.014	0.015	0.015	0.015
$1\frac{1}{2}$	0.010	0.111	0.013	0.014	0.015	0.016	0.016
$1\frac{3}{4}$	0.010	0.012	0.013	0.015	0.015	0.016	0.016
2	0.015	0.015	0.015	0.016	0.016	0.017	0.017
$2\frac{3}{4}$	0.015	0.015	0.015	0.016	0.016	0.017	0.017
$2\frac{1}{2}$	0.015	0.015	0.016	0.017	0.017	0.018	0.020
3	0.015	0.016	0.017	0.018	0.020	0.020	0.020
$3\frac{1}{2}$	0.015	0.017	0.018	0.019	0.020	0.020	0.020
4	0.020	0.020	0.020	0.020	0.020	0.021	0.021
$4\frac{1}{2}$	0.020	0.020	0.020	0.020	0.020	0.022	0.022
5	0.020	0.020	0.021	0.022	0.022	0.023	0.025
6	0.020	0.021	0.023	0.024	0.025	0.025	0.025
7	0.020	0.023	0.025	0.026	0.026	0.027	0.028
8	0.025	0.025	0.027	0.028	0.028	0.029	0.030
9	0.025	0.027	0.028	0.029	0.030	0.030	0.030
10	0.025	0.028	0.030	0.031	0.031	0.032	0.032
11	0.025	0.030	0.031	0.032	0.032	0.033	0.034
12	0.030	0.031	0.032	0.033	0.033	0.034	0.035

Diameter of work inches	Work Length in Inches						
	14	15	18	24	30	36	42
$\frac{1}{2}$	0.015	0.015	0.016	0.018	0.020	0.020	0.020
$\frac{3}{4}$	0.016	0.016	0.017	0.018	0.020	0.020	0.020
1	0.016	0.017	0.018	0.019	0.020	0.020	0.020
$1\frac{1}{4}$	0.017	0.017	0.018	0.019	0.020	0.022	0.022
$1\frac{1}{2}$	0.017	0.017	0.018	0.019	0.020	0.023	0.023
$1\frac{3}{4}$	0.018	0.018	0.019	0.019	0.020	0.023	0.023
2	0.018	0.018	0.019	0.021	0.021	0.024	0.024
$2\frac{1}{4}$	0.018	0.020	0.020	0.021	0.021	0.024	0.025
$2\frac{1}{2}$	0.020	0.020	0.020	0.022	0.022	0.025	0.025
3	0.020	0.020	0.022	0.024	0.025	0.027	0.027
$3\frac{1}{2}$	0.022	0.022	0.023	0.025	0.025	0.028	0.028
4	0.023	0.023	0.025	0.027	0.027	0.030	0.030
$4\frac{1}{2}$	0.024	0.025	0.025	0.027	0.028	0.030	0.030
5	0.025	0.025	0.027	0.029	0.030	0.032	0.032
6	0.027	0.028	0.029	0.031	0.031	0.035	0.036
7	0.029	0.030	0.031	0.033	0.034	0.037	0.038
8	0.031	0.032	0.033	0.035	0.036	0.039	0.040
9	0.032	0.033	0.034	0.036	0.037	0.040	0.042
10	0.033	0.034	0.035	0.037	0.038	0.042	0.044
11	0.035	0.035	0.036	0.038	0.040	0.043	0.044
12	0.036	0.037	0.038	0.040	0.042	0.045	0.045

CYLINDRICAL GRINDING

CAM-GRINDING PRACTICE

Automotive engine camshafts are drop forged from steel and case hardened to protect the wearing surfaces. In some instances carbon steel is used, although the more expensive alloy steels have been found to yield better results. The first step in the manufacture of a representative camshaft is to rough turn the center and main bearings. The next operation is to machine the cam contours. This usually is done in a special lathe equipped with means for advancing and retarding the cutting tools as the shaft revolves. Next the shaft is electroplated with copper after which the main bearings and the cam contours are rough ground. This, of course, removes the copper plating so that the carbon will penetrate the steel in the heat treating operation at the cam contours and bearing sections only. The sections between the cam that are protected with copper plate remain soft. Finishing operations consist of grinding the main bearings and finishing the cam contours. While the foregoing outline is not followed literally in all shops, it is fairly representative of the process.

The rough grinding of the main bearings before case hardening is a comparatively simple operation that does not differ materially from any common cylindrical grinding job. The work is located between centers and dogged at one end in the usual way. A back rest should be located over the center bearing to prevent chattering, however. The wheel should be manufactured alumina. As the object is to remove stock only, a coarse grit can be used; 24 straight or 24 combination. The grade should be medium and, of course, the operation is performed wet.

To derive the best results, the wheel and work speed must be considered together. Assuming that a peripheral wheel travel of 6000 feet per minute is used, the object sought is to obtain as high a work speed as possible, for the higher the work speed, the faster the traverse feed and consequently greater production. It might be well to start with a work speed of 40 feet per minute. If this speed makes the wheel act hard, reduce the wheel speed if possible and if this is not practicable, increase the work speed. This increase will make the wheel act softer. On the other hand, assume that the wheel appeared to wear away too readily. This can be overcome, of course, by reducing the

work speed, but the moment this is done production suffers. Thus the remedy is to increase the wheel speed which will make the wheel act hard. Of course, hard or soft wheels can be remedied by substituting different grades and this practice is to be recommended in preference to reducing work speed.

If the in-feed method of grinding is used, wherein the work is fed directly to the wheel without traversing, the element of traverse feed is eliminated which simplifies the problem somewhat. In this case it is practicable to use a medium work speed, say 30 feet per minute, and to adapt the wheel speed and the wheel grade accordingly. The entire subject is a matter of experiment well within the possibilities of the average abrasive engineer, and where production is paramount experimentation to increase grinder output is always in order. The finish grinding operation on the main bearings of the camshaft after it is hardened is a precision operation in the strictest sense of the word. The bearings must be round and straight within close limits. The common practice is to use a manufactured alumina wheel in grits ranging from 24 combination to 60 straight, in a medium soft grade. One grinding engineer will derive excellent results with a 24 combination grit, while another will persist in using a finer grit. The safest rule to follow, however, is to use as coarse a grit as possible, the finish on the work determining the selection. In some instances wheels bonded by the elastic process are used and they are productive of excellent results. As in the rough grinding operation, the traverse feed should be as rapid as possible and the other factors adjusted to conform to this.

Cam grinding is done on a cylindrical grinding machine fitted with a cam-grinding attachment. This device is fitted with a number of master cams mounted on one shaft, one master being provided for each cam to be ground. By means of a hand lever the cam roller is shifted from one master to the other as the cams are ground. Perhaps the most interesting factor pertaining to cam grinding is the method followed in producing the leaders. It is a foregone conclusion that these units must be accurate within very close limits and hardened to protect them against wear. In cam grinding, a leader of the desired outline is used to generate the proper cam curvature, but in making the leaders the practice is exactly reversed.

In place of the grinding wheel there is located a cast-iron disk which must correspond in size to the diameter of the wheel that will be used. By running a model cam over this leader it is evident that a certain motion will be imparted to the master cam shaft. Thus as a model cam revolves, a grinding wheel of the same size as the cam roller is brought against the leader or master cam, and as the master cam shaft revolves, getting its motion from the model cam working over the cast iron disk, an accurate contour is imparted to the leader. While the foregoing is simple enough two important factors must be taken into consideration.

1—The disk must be the same size as the wheel that is to be used in grinding the cams on regular production work.

2—The grinding wheel must be exactly the same size as the roll that is to follow over the master cams when they are used as leaders to generate finished cams on regular production work.

The master cams are roughed out before they are hardened and a simple method to follow in this operation is to mount each blank while soft on the roughing master cam spindle. Here it must be understood that two sets of masters are necessary in cam grinding—one for roughing and one for finishing. The attachment is started and as the model produces the necessary motion to the master the little wheel, which is the same diameter as the cam roller to be used, is brought to bear slightly against the side of the soft master. It makes an outline in this manner which can be followed by the toolmaker in removing the superfluous stock before hardening.

As before stated, the disk over which the model cam runs while making a master cam must be the same size as the wheel used in grinding the cams as a production operation. As all grinding wheels wear in use it is evident that after the wheel has worn away somewhat it will not grind the same shape on the cam as it did when it was new and of the correct size. Howard W. Dunbar furnishes a splendid graphic illustration of this phenomenon which is shown in Fig. 1. The model cam is in position bearing against the guide roll while a piece of cardboard is glued onto the master. In this position it takes the place of the cam to be ground under ordinary working conditions. The pencil on the swinging arms represents the grind-

ing wheel periphery. In carrying out Mr. Dunbar's experiment, a pencil mark is made on the cardboard, the master moved a few degrees and another mark made, and so on until the master has made one complete revolution. When the radius on which the pencil arm swings is changed to represent the periphery of a smaller wheel, a different shape cam will be drawn. As the three diagrams at the bottom of Fig. 1 illustrate, incorrect wheel sizes make a vast difference in the outline produced, even though the same master was used.

Thus it is apparent that after the grinding wheel is worn slightly it can not be depended on for accurate cam grinding

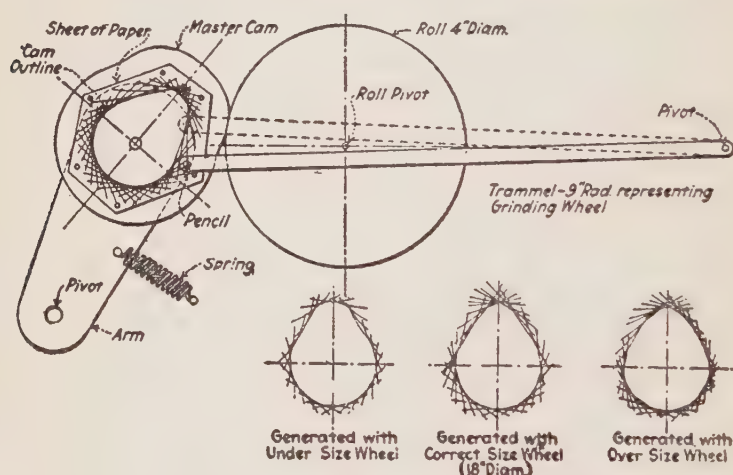


FIG. 1—RESULT OF WHEEL WEAR ON CAM ACCURACY

results. The remedy is to discard the wheel and substitute one up to size, or to provide several sets of masters generated from various size disks to represent wheel diameter decreasing by increments of $\frac{1}{4}$ to $\frac{1}{2}$ inch. These masters should, of course, be stamped to show the size wheel for which they were generated.

The importance of using correct size wheels or at least wheels in correct relation to the master cam should not be overlooked. There are in operation today numberless automobile engines which do not develop maximum power simply because their cam shafts are "off time," which was caused by a negligent operator failing to understand the vital importance of the

relation between a grinding wheel size and the master cams used with it in cam grinding.

As the master cams are all keyed onto their shaft in correct relation to each other to impart the necessary timing, it is evident that the driving dog must be located on the cam shaft in the right place to bring the cams in relation with the master. This is accomplished readily by means of a special locating device.

In rough grinding cams, a coarse, hard wheel generally is used, 30 grit being satisfactory in most cases. This wheel is operated at a peripheral travel of from 5000 to 6000 feet per minute, depending on local conditions. The work speed is comparatively slow, but this factor will be explained more in detail later. In rough grinding the cams, they are ground one after another to within predetermined limits leaving just enough stock in place to finish the cams properly after hardening. If too much stock is left it is obvious that the "case" will be ground through which would result in soft cams which would wear out rapidly. Thus extreme care must be exercised, even in the rough grinding.

In the finish grinding operation it is most always customary to use a fine grit wheel in elastic bond, 46 grit being generally satisfactory. While this operation is a comparatively simple one it is not without its drawbacks for great care must be exercised to prevent the cams "checking." These checks are cracks in the case-hardened surface that lead to serious difficulties. The work speed in cam grinding varies from a very slow one as the cam nose passes the wheel to an accelerated motion while the cam rise is being generated, and the rapid change in speed often results in undue heat which causes checks. F. W. Brown furnishes the following interesting data on cam checking:

Checks are caused in several ways. The two chief ones are incorrect heat treatment and the use of hard wheels. The checks sometimes are hardly visible to the naked eye, and in some cases they curl up after standing a few hours. This, of course, is only in extreme cases, but a normal check will cause irregular timing. I have seen checked cams that passed the inspection department and to all appearances looked all right, but a few hours' running in contact with the cam rolls caused

the checks to curl up and break off. This condition can be eliminated as far as the grinding is concerned by the use of soft wheels, correct work speed and a regular feed by the operator.

The human element enters to a large extent in the grinding of cams. Some men have a sense of touch that brings perfection that others never attain. In grinding cams after hardening I have found in six different automobile plants that a wheel speed of approximately 5500 feet per minute with the correct work speed for the different shaped cams to be satisfactory. Any standard make of grinding wheel selected properly will grind most cams that have come under my observation. I have found that elastic bond wheels running at a speed of 5500 feet per minute with a work speed of 42 revolutions per minute for roughing and of 22 revolutions per minute for finishing gave excellent results and eliminated checking. It is seen that two finish grinding operations were performed.

Individual cams are finished on an individual cam grinding attachment. At one time this type of cam was used extensively in automobile engine construction, but now its use is confined to single-cylinder engines such as marine and motor-cycle motors, etc. The process of grinding does not differ from that previously described. The attachment instead of having a multiplicity of master cams has one only. These attachments also are used for finishing the large chilled iron cams used in diesel engine practice. These cams often are 10 inches in diameter. In this case they are ground from the rough castings with carbide-of-silicon wheels.

Cam grinding practice has not changed materially in the past ten years, although great strides have been made in perfecting suitable wheels which overcome former difficulties due to the uneven work speed involved. The progress that has been made in producing cam grinding attachments and model and master cams has been along the line of refinements and a number of accurate and delicate machines have been devised by leading grinding machine manufacturers for checking the truth of model and master cams.

CENTERLESS GRINDING PRACTICE

The principal elements of a modern centerless grinding machine, according to George W. Binns, are the grinding wheel, regu-

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lating or feed wheel and the work rest. The work rest may be provided with suitable guides to lead the work in line with the wheels and receive it therefrom. These elements may be arranged and combined in a number of different ways, but the fundamental principle involved is the same in all cases. The grinding wheel in action presses the work against the work rest, due to what is called the cutting pressure, and also against the regulating or feed wheel by what may be called the cutting contact pressure,

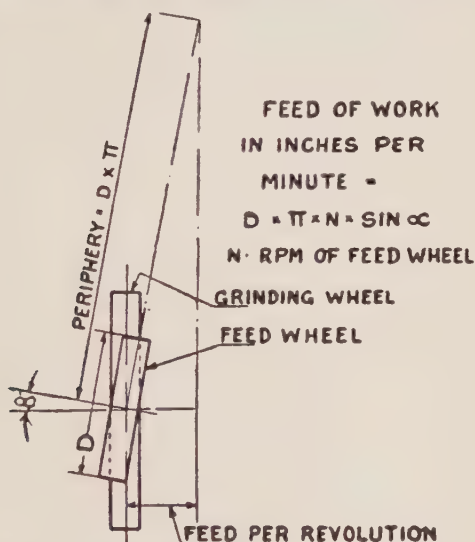


FIG. 2—TRAVERSE-RATE DATA FOR CENTER-
LESS GRINDING

which is that pressure which keeps the work in contact with the regulating wheel. This wheel generally is of a material similar to the grinding wheel which provides a surface sufficiently rough to prevent any slippage between it and the work, causing the work to assume the same surface speed as the feed that of the feed wheel.

Lateral movement of the work past the grinding wheel also may be imparted by the regulating or feed wheel when desired. With wheels which have a peripheral contact with the work, this is accomplished by a tilt or angle between the feed-wheel spindle and the axis of the work. That is, their centers do not fall in the same plane. Where the feed wheel has face contact with the work, as in the Reeves grinder, the same action is obtained by

having the contact with the work at a point slightly below or above the center. Fig. 2 shows how to figure the rate of traverse of the work through a centerless grinding machine of the Cincinnati type. This is a theoretical feed based on the assumption that there is no slippage of the work whatsoever in its contact with the feed wheel. It is said to be remarkable how close actual results check with the theory. There is rarely an error of more than 2 per cent. In ordinary centerless grinding practice, the work is fed between the wheels a number of times, a small amount being removed at each pass. The number of passes necessary for a given job is governed by several factors, such as the diameter of the work, the amount of metal to be removed, the grit and speed of the grinding wheel, etc. Further data on this subject are given under Centerless Grinding of Auto Parts in this section.

An interesting development in centerless grinding consists of the so-called shoulder grinding of pieces that, due to their design, cannot be passed through the machine. In this category are included the ordinary headed work such as bolts, valve tappets and valves. Here the work is placed between the wheels on a work rest and the wheels are brought in a definite amount, thus sizing the work. By this method it is necessary to have the wheels as wide as the ground portion of the work is long. The infeed operation has been worked out very efficiently so that the movements of the operator are reduced to a minimum. There is one movement only required of each of the operator's hands. His right pulls the lever down to a stop. This closes the wheels together for sizing the work. The return movement of this hand automatically ejects the piece while the left hand drops a new piece into position. The movements of the operator are therefore so simple that he does not have to think while operating the machine.

Work of this nature is usually finished in two cuts, one for roughing and the other for finishing and accurate sizing. The production averages between 10 and 15 pieces per minute for each cut, giving a net production of five to eight pieces per minute and this production compares favorably with the straight-through method for the equivalent amount of grinding. Automatic attachments for the infeed method relieve the operator of

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all hand movement and when a hopper feed is used in connection with the machine its operation is practically automatic.

The infeed method of grinding opened a very large new field including form work, taper work and long shafts which have a short portion only ground. In fact, centerless grinding has already been applied to a wide variety of work and on classes of work which was thought a short time ago to be absolutely impossible.

Perhaps the most important factor pertaining to centerless grinding, according to J. E. Caster, is that of generating round

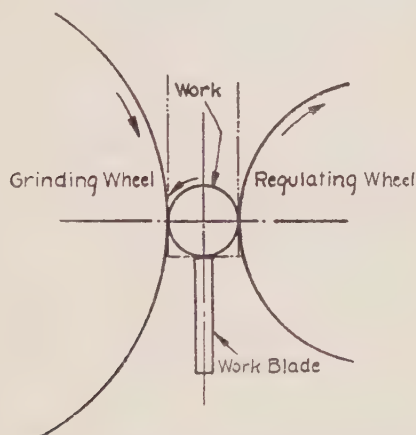


FIG. 2—TYPICAL POSITION OF WORK
IN CENTERLESS GRINDING

surfaces. It is not difficult to understand why work is ground round on a cylindrical grinder with centers, because the centers determine an axis of revolution about which is generated a cylinder; the diameter of this cylinder being determined by the distance between the centers or axis of revolution and the periphery of the grinding wheel. But in the centerless grinder, we have no centers and at first glance no method of controlling the roundness of the work. We can understand how the diameter is controlled because this is dependent upon the distance between the active surfaces of the two wheels, but a constant diameter does not mean a round piece.

First, let us consider the two wheels with a blade mounted between, and a piece in the grinding position, as shown in Fig. 3. For the purpose of illustrating our point, we have placed the

center of the work in a line with the centers of the wheels. The blade has also been shown with a flat top. Here we have the three sides of a square and any hollow spot in the work which is placed in contact with the regulating wheel, will cause a corresponding hump or high spot to be ground diametrically opposite and any high spot which comes in contact with the regulating wheel will generate corresponding low spot opposite. This is shown in Fig. 4. The blade influences this action somewhat by elevating or lowering the center of the work as humps or flats pass over it, but the point is well illustrated without consider-

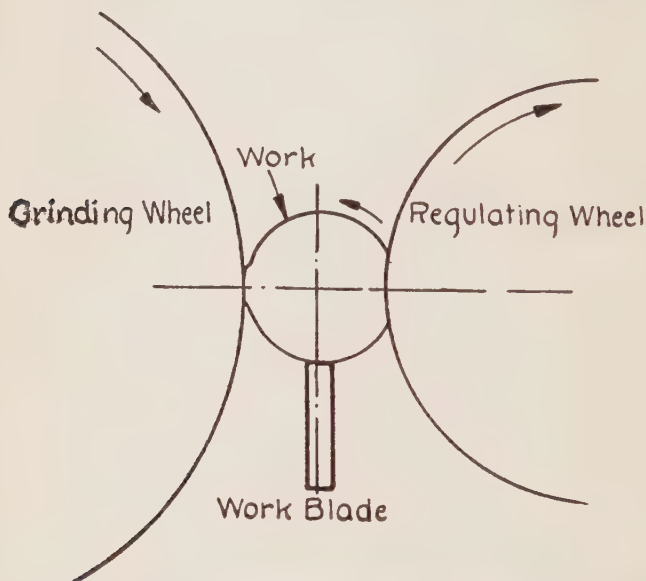


FIG. 4—THIS SETUP SHOULD BE AVOIDED AS IT CAUSES OUT-OF-ROUND WORK

ing this factor. If we should grind work in this position we will have pieces which are of constant diameter but are not round. One of the most common shapes generated by this setup is shown in Fig. 5, and is known as the 3-arc triangle, having a constant diameter, but not round.

In Fig. 6 we see that the work has been elevated so its center is above the line drawn between the centers of the wheels. With this setup, a low spot in contact with the regulating wheel will cause a high spot to be generated at the grinding wheel contact, but not diametrically opposite, and as the piece being ground is

rotated, the high and low spots will not come in the same relationship as shown before and we will get a gradual rounding up effect. Further to assist in this rounding up action, we have found it to be advantageous to use a blade known as an angle top blade, as shown in Fig. 6. Here we have broken up all the angles of contact and obtain the maximum rounding effect.

There is another action which greatly influences the rounding up effect and is shown diametrically in Fig. 7. Two lines,

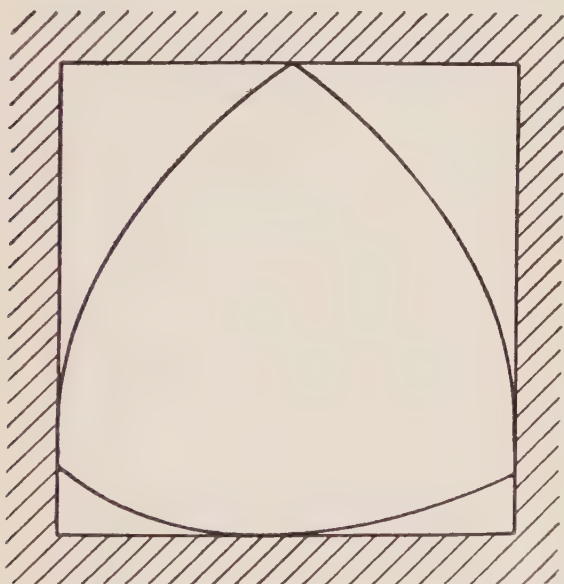


FIG. 5—THE SO-CALLED 3-ARC TRIANGLE WHICH IS CAUSED BY AN INCORRECT SETUP

A A and *B B*, have been drawn tangent to the point of contact of the work with the wheels, and another line, *C C*, shows the plane determined by the angle top of the blade. We will see here that if a low spot comes in contact with either the plate or the regulating wheel, as in the case of the piece shown in dotted lines, that the approximate center of the work will be lowered. As the work settles down, or is lowered, the wheels in effect, move in, due to the V shape of the two tangent lines *A A* and *B B*.

Since the wheels are, in effect, closer together as the work settles or lowers, instead of grinding a high spot at the grinding wheel contact which is equal to the size of the flat which is in

contact with the regulating wheel, a high spot or hump will be generated which is proportionately less than low spot, depending upon the angle α of the tangent lines, together with the angle of the plane of the plate. Here it is seen we have a corrective effect in addition to the averaging effect explained above. This action is very complex, but from experience we know that it is

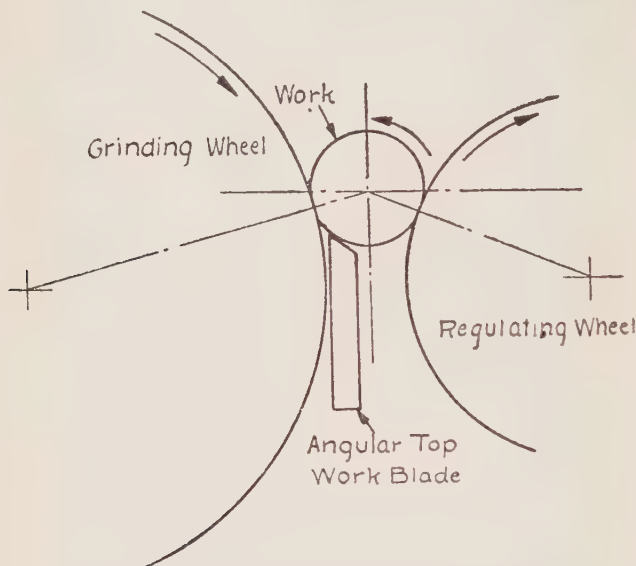


FIG. 6—THE WORK IS ELEVATED SO THAT THE AXIS OF THE PIECE IS ABOVE THE WHEEL CENTER

very corrective and if a piece very much out of round, say 0.010 to 0.012-inch, is started through the machine and a light cut is taken, only the high spots will be ground, and from the very first spark the machine starts to generate the largest true cylinder which is possible to be generated out of the irregular outline in the rough piece.

The higher above center the work is placed, the quicker the rounding up action; the limit being when the work kicks up from the blade due to the greatly increased vertical components of the lines of pressure. This fact is proven every day, as the regular cure for out-of-roundness is higher placement of the work, all of which agrees with the theory of correction, since the higher the work the larger the angle α . It is possible to go higher with soft wheels than it is with hard ones. This is because the

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contact pressure is not so great, which decreases the tendency to force the work up. Naturally, when a particular piece of work is had which is hard to round up, the work can go extra high by using a wheel that is extra soft. A good normal grinding position is to have the center of the work approximately half the diameter of the work above the center of the wheels. For work that is very small go higher, and for work that is large, go lower. In the normal type of grinding, that is, by through

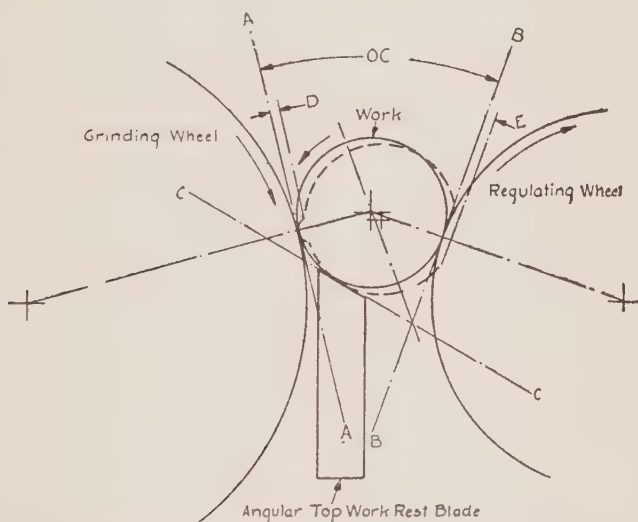


FIG. 7—DIAGRAMMATIC ILLUSTRATION OF THE FACTORS THAT INFLUENCE ROUNDNESS OF WORK

feed methods, it is not possible to round up the job in one pass and one reason for this is that the work continues to rotate on at least part of its rough diameter until it has passed all the way into the wheels, and so it generally happens that one end of the work becomes more accurately round than the other on the first pass.

There are two broad classes of centerless grinding. First, through-feed method, and second, the in-feed method. In the in-feed method, the wheels are placed with the axis of the spindles practically parallel, so that very little traverse effect will be obtained. The work, which generally has a shoulder, head, or some underground portion larger than the ground diameter, is placed between the wheels resting on the blade and against an

end stop which is to the rear of the wheels. The wheels are then gradually brought together to a predetermined distance which grinds the work to size.

In this way the stock is reduced simultaneously over the entire length of the piece being ground while in the through-feed method, the reduction is gradual, extending from end to end as the work passes through the wheels. The same consideration for rounding up work holds good whether we are grinding by the through-feed or the in-feed method. It is also possible to generate a cylinder if the center of the work is below the center line of the wheel, and oftentimes, due to certain characteristics of the piece being ground, this setup is used. However, the rounding action is not as rapid as in a case of grinding above center.

A fundamental requirement of work turned out by the centerless machine is that it must be straight. The first consideration for grinding a piece straight is to have the wheels wide, and it is easy to grind work perfectly straight that is not longer than the wheels are wide. If, however, the piece is much longer than this, then it becomes important to consider what advantages may be taken of the various methods of grinding. We saw previously that if we wished to round up a piece, it was desirable to have it make as many revolutions as possible when passing through the wheels in order to give time for the averaging and correction action, but in straightening a piece it is desirable to have the angle of the lead or spiral advance of the work as great as possible. The farther the work is advanced into the wheel per revolution, the greater the tendency to straighten it, and it also often happens that there is considerable advantage in going below center on crooked work because this causes the work as it revolves to throw the high point into the wheels instead of away from them and helps to prevent crooked work from chattering, due to the spring of the piece. There are also difficulties in grinding work straight which are caused by faulty set ups. Directly to the front and to the rear of the grinding wheels are placed guides which accurately line up the work with the wheels before and after being ground.

H. F. McClung gives the following data pertaining to centerless grinding operations in automobile manufacturing plants:

While space prohibits a detailed description of the large number of operations performed by the centerless grinding ma-

chine, we will describe one or two operations which will show the accuracy and large production possible on modern grinders. When we realize that present-day motors are designed to run from 2600 to 3600 revolutions per minute and with every second revolution a power impulse obtains, which causes wear on the reciprocating parts of the motor, it is readily seen that these parts must be made and assembled with the utmost precision. In one large automobile plant the following grinding operations are performed in the manufacture of piston pins:

The pins come to the grinders direct from the heat treating department at a diameter of 1.015 to 1.017 inches. The first two operations consist of two passes through a centerless grinder, removing 0.007-inch per pass, with a production of 250 pins per hour through both operations. The pins then go to another centerless grinder for the semifinish operation, consisting of one pass removing 0.002-inch stock and one sizing pass removing 0.001-inch stock, with a total production through both operations of 500 pins per hour. Then finishing operations are performed on another centerless grinder, the first pass removing 0.001-inch stock and the finish pass removing 0.0002-inch stock, with a total production through both operations, of 500 pins per hour. The pins are then taken to a lapping machine for the final operation.

The finished pins are then taken to the inspection department where they are checked on a fluid gage and V-block for size, taper, and eccentricity. The pins are held to 0.0002-inch for taper and 0.0001-inch for out-of-round. The diameter is held to limits of 0.9986 to 0.9988-inch and are separated for assembly purposes into divisions varying by 0.0001-inch. In order to keep up this production schedule and attain such accuracy and the finish demanded, it is necessary to have grinding wheels of the proper grade and grain for each operation. The centerless grinders in the plant in question are also used for fast production on various other parts, such as the gear shifter rods, steering knuckle pins, reverse idler shaft, brake rods, oil pump shaft, brake cams, valve push rods, and various straight bushings.

The following data pertaining to the centerless grinding of drill rod was furnished by B. K. Price:

In the production of drill rod steel, in most plants, centerless grinding has come to supplant the finish pass over the draw bench. Not only has the grinding been found to expedite produc-

tion, but it holds greater accuracy and provides a finer finish. On the two latter features special emphasis is placed. It is essential, in fact, that limits less than 0.0005-inch in diameter be maintained on all sizes.

At one of the larger plants devoted to drill rod manufacture, the rod steel is of high carbon content. It ranges from $\frac{1}{4}$ to $1\frac{1}{2}$ inches in diameter and on an average, 3 to 12 feet in length, although occasionally 18-foot lengths are produced. The rods are run through a vertical type centerless grinder. The work rests on a live support, the feed wheel, and rotates with the same surface speed as the feed unit. The feeding action is provided by the angle of the feed wheel to the grinding wheel, which imparts a screw action to the work. This angle is usually set at one to four degrees.

The grinding wheel is manufactured alumina, 60 grit, L grade, 18 inches in diameter, with a 4-inch face. The speed of this wheel is held constant, regardless of the size of the work, at around 1400 revolutions per minute. The feed wheel is rubber bond, 10 inches in diameter, 8 inches face, 60 grit. As the feed wheel is wider than the grinding unit, it exerts a rotating and feeding action before the grinding wheel is reached and after it is passed. No pressure from the grinding wheel is necessary to produce rotation. The speed of the feed wheel is variable, and is usually regulated by a rheostat, which can be set to provide 25 different speeds for each degree of angle to which the wheel is set. Feeds of from one to 90 feet per minute are available.

Positive control of the work is provided by two guide bars so arranged that once set they maintain their position as the grinding wheel wears. They are set parallel to the axis of the larger wheel. Depths of cuts are regulated by a hand wheel, operating through a worm and worm wheel and a jack screw to raise the feed wheel toward the grinding wheel. The hand wheel dial is graduated in tenths of thousandths and one revolution produces a feed of 0.01 inches. The small bars, naturally, go through faster than the large. At the plant in question approximately 0.002 to 0.003 inches of material are removed in the course of the operation, following which the rods are buffed to impart a high polish.

W. W. Seabury furnished the following data pertaining to centerless grinding operations at the plant of the Ford Motor Co.

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As this plant is world-famed for its intensive production operations, the data can be taken as authoritative of present-day economical centerless grinder operation:

In finishing piston pins by the centerless method at the Ford plant, a production of 66,000 pins is obtained with a complement of 57 men operating 26 machines. Limits are 0.0004-inch for roundness and taper. Some idea of the accuracy obtained is had from the fact that a pin will not pass inspection if it is out 0.0002-inch in roundness or taper. On tractor pins 1 $\frac{1}{2}$ inches in diameter, 0.018 to 0.02-inch is removed from the diameter in three roughing passes. About 0.0035-inch is removed in five finishing operations as follows:

Pass	Material removed, inches
1	0.0012
2	0.0008
3	0.0007
4	0.0005
5	0.0003

To detect inaccuracy in the work at inspection, the gaging is done by a method using the 3-point principle employed in the centerless grinder. A V-block and magnifying dial are used. Experience determines the best angle of the driving-wheel axis with that of the grinding-wheel axis. It depends upon the type of work, kind of finish required, and the amount of stock to be removed. In the case of the tractor piston pin, an angle of 3 degrees is satisfactory.

The centerless grinder had made it possible to machine light pistons with the great accuracy without the distorting effect of chucking, which was necessary in a turning machine. It is the Ford company's experience that in the turning of pistons the intermittent striking and receding action of the tool in going over the piston-pin hole makes it almost impossible to produce a round piston, regardless of the care and precautions taken to use lighter cuts and to relieve a section around the piston-pin hole. It has not been unusual to find pistons having a wavy appearance the length of the piston after the finish-turning operation, regardless of the heat treatment or seasoning of the metal. The cause of this is attributed to the variation in the texture of the metal and the consequent springing action of the tool due to the variation in hardness commonly called hard spots.

Centerless grinding greatly simplifies the problem of finish-

ing pistons accurately. In the case of the cast-iron piston the rough-turning operation is performed first, after which the finishing operation is done on the centerless grinder. The amount of stock removed is 0.003-inch in the first operation through the centerless machine and 0.001-inch on the finish operation. Although the production runs about 50,000 pistons per day, the accuracy had been increased with the centerless machine so that the tolerance is now 0.0005-inch, plus or minus, as compared with 0.002-inch when the finish operation was turning one. The life of a grinding wheel on this job is about 50 days. The size of wheel is 20 inches in diameter, 4-inch face, 9-inch bore. It is dressed about four times in 24 hours.

The machines used for centerless grinding at the Ford plant by the through feed method embody a grinding wheel and regulating wheel mounted with their axes in a horizontal plane and opposite each other. Another type is the vertical opposed type having the grinding wheel mounted directly above the regulating wheel. The latter type has the advantage over the former for grinding narrow work of large diameter, as, for example, the Ford brake shoe, a casting about 1 inch wide and 8 inches in diameter, held to within 1/64 inch limits in the foundry.

The 0.032-inch of stock to be removed is ground off in the vertical-type centerless grinder in two passes and the limits maintained are .002-inch for roundness. The cutting capacity is about five cubic inches per minute. This production has been obtained after persistent development of the machine as a whole, and especially the grinding wheel. It might be well to mention that at the start of the use of the centerless grinder on this part, 1500 shoes had been ground per wheel, but after considerable effort on the part of wheel manufacturers, the average shoes per wheel ran from 15,000 to 20,000, dressing the wheel only once at the start. The wheel is used to within $\frac{3}{4}$ inch of the hole. The speed of the grinding wheel on the first-operation machine is 1000 revolutions per minute and on the second-operation machine, 1280. The size of grinding wheel is 18 inches diameter, 4-inch face, 7 $\frac{1}{2}$ -inch hole. The regulating wheel is 9 $\frac{1}{2}$ inches in diameter with an 8-inch face. It is important to keep the grinding wheel sharp and free from gumming by using plenty of clean water and enough soda to prevent rusting. A solution of 92 per cent water, 5 per cent sal soda and 3 per cent oil is satisfactory.

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CENTERING WORK

Great care should be exercised in centering work for the grinding machine, for if the centers are not true accurate results cannot be expected. The centers must be a true 60-degree angle (American practice) and the operator must make sure that the drilled hole below the countersink is deep enough to accommodate the end of the center. As a general rule, combination drill and countersinks are used for centering work as they reduce the centering operation by practically one-half.

No matter how carefully the work has been centered, accurate results in grinding cannot be assured if abnormally heavy lathe cuts have distorted the centers. In this case it is a good plan to re-center the work before it is brought to the grinding machine. Attention to this slight detail, especially when working on very fine operations, will save trouble.

CHATTER MARKS

Chatter marks are a detriment to efficient grinding. In connection with cylindrical grinding, chattering can be laid to a number of causes such as the grinding machine centers not fitting those in the work, loose wheel slide, loose wheel spindle, head or tailstock loose in the platen, incorrect relation between the wheel and the work speed, lack of backrests, wheel not trued correctly, wheel out of balance and end play in the work on its centers. The remedy is to go over the machine carefully with the foregoing factors in mind to locate the difficulty.

COOLING SOLUTION

A solution of soda water or a prepared grinding lubricant should be used in cylindrical grinding operations whenever possible. The rule also applies to surface grinding, knife grinding, etc. The larger machines are equipped with cooling systems, the solution being supplied in a constant stream at the point of grinding contact. Some of the smaller universal grinding machines are not equipped with cooling systems. A solution composed of sal soda and water gives excellent results in general cylindrical grinding. Plain water is not practicable as it rusts the machine and the work. Various manufacturers of grinding machines do not agree as to the amount of soda to put in a given amount of water in making up the solution. Three

well known makers of grinding machines recommended the following solutions: One pound of soda to two gallons of water, one pound to four gallons and one pound to eight gallons. Thus a wide range is to be had. It is safe to assume that any amount between the two extremes would be satisfactory. From an economical point of view, however, the formula calling for the least amount of soda is the cheapest. The object of the soda is to prevent rust so that any desired amount that will bring about this result should be satisfactory.

The various grinding compounds that are on the market give good results. In general it should be stated that a thick solution should not be used when grinding up to shoulders as it prevents the operator seeing the wheel edge as it approaches the shoulder. The question as to whether grinding compound carries disease germs is a moot one. Many years ago when lard oil was used extensively in screw-machine practice it was thought that it carried disease germs. Thus if the operator had a slight abrasion on his hand or arm he stood a chance of becoming inoculated. For this reason, the use of a strong antiseptic was advocated in many instances. As a matter of fact, such solutions as lard oil could be sterilized by boiling. Regarding the use of antiseptics in grinding compounds, one of the most prominent grinding machine manufacturers states as follows:

We have never found it necessary to consider the use of antiseptic agents in grinding compounds, as there has been no record of any infection coming from that source. We have had some questions arise regarding the cutting compounds used on screw machines and other similar tools, but even here the analysis has seemed to indicate that there was no contamination of a character which might cause infection.

CRANKSHAFT-GRINDING PRACTICE

In the manufacture of crankshafts, no two plants follow exactly the same routine, but the general sequence of operations after the shaft is ready for the initial grinding operation are as follows in a representative plant:

- 1—Rough grind ends.
- 2—Turn pins.
- 3—Drill for lubrication.
- 4—Rough grind pins.
- 5—Straighten.
- 6—Semifinish pins.
- 7—Finish pins.

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- 8—Rough finish No. 2 and 3 center main bearings.
- 9—Straighten.
- 10—Finish No. 2 and 3 center main bearings.
- 11—Straighten.
- 12—Finish No. 1 and 4 main bearings.
- 13—Finish both outer ends.
- 14—Keyseat both ends.
- 15—Drill starting crank hole.
- 16—Straighten.
- 17—Rough balance.
- 18—Finish balance.
- 19—Complete drilling operations.
- 20—Polish.

The shaft in question has six pins each $2\frac{1}{4}$ inches in diameter and $1\frac{11}{16}$ inches long with $\frac{1}{8}$ -inch fillets at the corners and four main bearings. The two center main bearings are $2\frac{1}{4}$ inches in diameter and $1\frac{23}{32}$ inches long, while the outer bearings are $2\frac{1}{4}$ inches in diameter, one being $3\frac{5}{8}$ and the other $2\frac{1}{4}$ inches long. The back end of the shaft also includes the taper fit for the flywheel, $2\frac{5}{8}$ inches long and $1\frac{3}{4}$ inches in diameter at the large end, and two other ground portions, $1\frac{1}{4}$ inches in diameter and $\frac{3}{4}$ inch long; and $1\frac{1}{8}$ inches in diameter and $1\frac{23}{32}$ inches long, while the outer bearings are $2\frac{1}{4}$ inches in diameter, one being $3\frac{5}{8}$ and the other $2\frac{1}{4}$ inches long. The back end of the shaft also includes the taper fit for the flywheel, $2\frac{5}{8}$ inches long and $1\frac{3}{4}$ inches in diameter at the large end, and two other ground portions, $1\frac{1}{4}$ inches in diameter and $\frac{3}{4}$ -inch long; and $1\frac{1}{8}$ inches in diameter and $1\frac{3}{4}$ inches long. In grinding both pins and main bearings, 0.035-inch of material is removed in the first roughing operation, 0.01-inch in semifinishing, and 0.008-inch in finishing. From the list of operations it will be noted that finishing allowance would be necessary to compensate for irregularities brought about by the internal strains in the steel adjusting themselves.

For finishing the main bearings the crankshaft is mounted between centers in the usual way and it always is backrested at the portion of the shaft in process of grinding. This is important for without a backrest properly adjusted, chattering would result. The usual procedure in finishing main bearings is to employ a wheel slightly narrower than the width of the shortest bearing so that the work must be traversed slightly. Accurate fillets on the bearings are of course necessary for without the fillets the shaft would break in use. The wheel corners are trued to the desired radius by means of a special device carrying a diamond. The

diamond holder is adjustable so that radii of any desired curvature can be had. It is necessary to retrue the wheel corners each time the wheel face is dressed.

A double-head crank grinder is the most economical machine to employ for finishing the crank throws. The shaft is driven from each end, the ends being gripped in offsets which are adjustable for different crank throws. Both heads are driven simultaneously through gearing and a shaft that connects the heads. The work is backrested at the point of grinding to avoid chattering. In finishing the pins, the usual procedure is to run the shafts through the department in lots of say 100. Thus the machine is set up for work on all pins that lie in the same plane and after these are finished the machine is reset for pins in another place. Where the production schedule warrants the use of several machines, one grinder can be kept continuously on one operation which keeps production at an even flow.

The selection of wheels for crank grinding is a problem that must be settled by each grinding wheel supervisor as local conditions usually influence the grit and grade selection. Thus careful experimentation is the only reliable guide. However, the machines in a representative plant are equipped with manufactured alumina wheels. The wheels used for roughing and semifinishing both the pins and main bearings are 36 grit, S grade on the universal scale, vitrified bond. The peripheral travel is 6000 feet per minute. The high peripheral speed in connection with a hard wheel is necessary as the wheel is subjected to very heavy duty. Finishing is performed with wheels manufactured alumina wheels is 36 grit, M grade, vitrified bond. These wheels are of the special so-called refined material which is quite friable when compared with the ordinary manufactured abrasive of commerce. That the wheels prove satisfactory for the work is apparent as the grinding time for one shaft including the three operations, that is roughing, semifinishing and finishing of the line bearings and pins is 51 minutes. No traverse feed is used in pin grinding, the wheel being trued on its sides to exactly the width of the pins. W. Paul Conant furnishes the following data pertaining to the manufacturer of crankshafts on a quantity basis:

The rough crank as it comes from the centering machine first is sandblasted to remove all foreign matter. A rechecking by an inspector follows this to catch any possible flaws overlooked

in the forge shop. The crank then is given a number for record purposes and sent to the lathe department for the initial operation. The conveyance used is a specially designed rack with ball bearing casters to insure easy propulsion. This rack is built so that as the various surfaces are finished they are protected from harm. The centers of the shaft are first tested and then the center bearing is rough turned leaving 0.05-inch of stock.

In another engine lathe, the main bearings are spaced and roughed out and the crank checks faced. A templet is used to check the accuracy of the operation. The limits are the same as for the center bearing. Following this operation the flange is turned on its outside diameter and to width, 0.05-inch of material being left for finishing on the diameter and 0.075-inch on the width. The final operation on this surface is to finish turn in a lathe.

The rear bearing and oil groove next are rough turned after which the front bearing and gear fit are machined. A floor inspector helps in these operations by constantly checking the work. The machines next in line are pin lathes which rough turn the pins leaving 0.06-inch of stock for rough and finish grinding. The diameter is held to 0.006-inch and the width to 0.003-inch. The radius also is kept to a close safe margin to insure the wheel against excessive wear and resultant loss of production and accuracy. The foregoing operations are all on machines lined up in batteries so the movement of the racks of stock do not slow up the continuity of the operations. The greatest single movement does not usually exceed four feet.

The cranks finally are inspected and straightened where necessary before going to the grinders. The first grinding is done on a plain grinder capable of accommodating work 14 inches in diameter and 96 inches long. This operation consists of roughing the line bearings and gear fit. The wheel is manufactured alumina, 20 inches in diameter, from $2\frac{1}{2}$ to $3\frac{1}{4}$ inches face, 3015 grit, P grade. The amount of stock left for finish grinding is 0.015-inch and the limits are 0.001-inch on the diameter and the width. Each size crank has its master and production snap gages, all under the care of the inspection department. They are checked carefully at regular intervals.

The pins then are rough ground on a pin grinder equipped with special attachments. About 0.018-inch of stock is left for

finish grinding and the width is held to 0.002-inch which is pre-determined by dressing the grinding wheel. The wheel width is 0.025-inch oversize and it is dressed by the operator after setting up. A special turning device attached to the headstock helps this operation and insures parallel sides. The same condition also applies to the finishing wheels. Pin grinding machines of the type previously mentioned are used next to finish grind the pins, using manufactured alumina wheels 24 combination grit, N grade. The roughing and finishing grinders are run in pairs, the close contact of the operators helping the complete operation very much. Any difficulty is quickly discovered and overcome, practically eliminating the production of scrap. The pins are held to 0.00025-inch on the diameter and 0.001-inch on the width. They must be round, free from chatters, wheel marks, and show a clear surface. Accurate grinding with proper wheels makes the finish a minor detail, as far as trouble in getting it is concerned. Diamonds are used for dressing in all finishing operations and mechanical dressers on all roughing operations. The cranks then pass through another complete inspection before the line bearings are finish ground. Plain grinders are used. They are fitted with manufactured alumina wheels, 18 inches in diameter, 2½-inch face, 46 grit, M grade. Nothing impairs finish or accuracy quite as much as excessive stock removal with a finishing wheel, especially when grinding the special alloy steel used in the high grade automotive products.

The flange next is ground on the outside diameter which completes the finish grinding. This is held to 0.00025-inch as the flywheel is later located from this dimension and is balanced again as an assembly.

The cranks then go to the engine lathe finishing department where the gear fit is cut to length, the flange faced, and the oil retainer shoulder finish turned. The oil lines are then drilled on a special drill press with cleverly designed jigs that entirely eliminate any chance of marring the finished surface unless subjected to the grossest carelessness. Following this the cranks are balanced.

The final abrasive operation in the manufacture of crankshafts consist of removing the minute marks left by the wheel. In some instances the shafts are rotated while the main and pin bearings are finished with fine-grit abrasive cloth held in polish-

ing clamps. A special machine called a crankshaft buffing machine sometimes is used. It is the usual practice to operate two of these machines, one for main and the other for pin bearings. The shaft is mounted on offsets at each end so that two pins which are in line revolve about a common axis as they are fed toward the two wheels with which the machine is equipped. A locating device is incorporated which sets the two wheels the correct distance apart for finishing any two pins that lie in the same plane. After these are finished the shaft is relocated in the offsets and the wheels are shifted to finish two more pins.

The wheels in question are hard Maxican felt, 26 inches in diameter and 1 11/16-inch face. They are operated at an approximate peripheral travel of 8000 feet per minute. The abrasive used is tripoli and in some instances a white buffing compound such as Vienna lime is employed. The abrasive is applied to the wheels locally. The amount of material removed is of course very slight, not over 0.0002-inch and the finish thus produced amounts to a high precision polish so that the bearings can be fitted with a minimum amount of labor.

The latest development in the superfinishing of crankshafts, however, consists of honing in a special machine called a crankshaft honing machine. A description of this operation is given in Section X.

CROSS SLIDE ADJUSTMENT

If the cross slide is not adjusted and oiled properly it will not feed evenly. This results in the work "jumping in." This is caused by the feed mechanism putting a strain on the wheel slide and as soon as it is great enough, the slide gives, causing the work to dig into the wheel. This will ruin the work, and in rare instances it has been known to fracture the wheel. Thus the wheel slide should be kept in correct adjustment and oiled at frequent intervals.

DEPTH OF CUT

In cylindrical grinding practice, the depth of cut refers to the amount the wheel is fed toward the work at each reversal of the platen, or of the wheel head, according to the design of the machine. Practically all cylindrical grinding machines are equipped with devices that feed the wheel forward automatically at each reversal of the work. On production work, the depth of cut must be heavy to expedite the operation. When rough-

ing, the wheel should be fed in until it sparks heavily. On tool grinding operations, however, an abnormal depth of cut is not necessary. On any kind of hardened work, the depth of cut must not be deep enough to cause undue heating. In tool room grinding, the automatic cross feed often is discarded, the operator feeding the work in by hand as occasion requires.

Some years ago, the late George I. Alden originated the grain depth of cut theory as applied to the operation of grinding wheels. Robert J. Spence furnished the following data which pertains to a test of Mr. Alden's theory:

Mr. Alden advanced the theory that the thickness of the chip at $W S$, Fig. 8, as affected by a change of work speed, wheel speed,

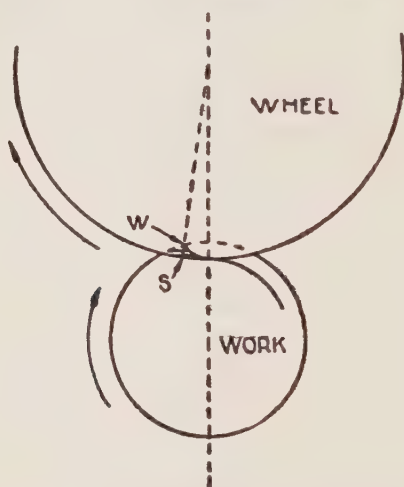


FIG. 8—MAXIMUM GRAIN DEPTH OF CUT

work diameter and wheel diameter, is the criterion by which may be judged, and regulated, the wheel wear toward the successful working of the grinding wheel. The thickness of the chip at $W S$ he described as the maximum grain depth of cut. Among other theoretical conclusions he advanced the following: Other factors remaining constant, increase of wheel speed decreases grain depth of cut. Similarly, diminishing the diameter of the grinding wheel increases grain depth of cut. Also, as a related truth, a decrease in grain depth of cut makes a wheel appear harder and an increase in grain depth of cut makes it act softer. In a test to determine the effect of wheel speed and wheel diameter on the

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grain depth of cut, the material ground was a bar of machinery steel, 3 inches in diameter and 15 inches long, turned down on one end to accommodate a driving dog and to present a traverse zone free from shoulder interference. The wheel used in this test was alundum, 24 combination grit, L grade, vitrified bond. Its original diameter was 13 inches, but to meet the conditions of the test it was subsequently trued down to diameters of 11 and $8\frac{1}{8}$ inches, respectively. A narrow wheel face, one inch, was used to obtain effective wheel wear. The machines used were Norton cylindrical grinders capable of accommodating work 10 inches in diameter and 50 inches long and 6 inches in diameter and 36 inches long, respectively. Both machines were in good condition. The wheel speeds were as follows:

Size of machine inches capacity	Wheel speed, revolutions per minute	Wheel speed, surface feet per minute
10 x 50	1400	4765
10 x 50	1650	4752
10 x 50	1400	4030
6 x 32	1775	5100
6 x 32	2400	6900
6 x 32	2400	5100

The variation in surface feet per minute for number of revolutions per minute was obtained by changing the diameter of the wheel.

Before each test, the wheel was dressed coarsely with a diamond, the final pass across the face being one of 0.003-inch depth at the slowest table traverse. For reducing the diameter of the wheel radically, a huntington dresser was used, followed by the foregoing treatment with the diamond.

The work was run at a speed of 80 feet per minute, using three-fourths of the wheel face. This required a table traverse of 72 inches per minute. The wheel was fed in at the rate of 0.001-inch per pass, for 80 passes, giving a total feed of 0.08-inch. This feed was used throughout the test. The test was started with a 13-inch wheel, it being fed in until the total feed had been given. The amount of stock removed from the bar was determined by the difference in diameter before and after grinding. The difference between material removed and total feed gave the wheel wear. Tests with the same diameter were repeated for verification. The Spindle belt was then changed to another pulley step to give a higher wheel speed consequently

requiring a reduction in wheel diameter to maintain the same number of surface feet per minute, to obtain data regarding effect of wheel speed the pulleys were again changed, the diameter remaining constant, and tests made with the wheel run at a lower surface speed. By such a manipulation of pulleys and diameters on both machines a wide range of surface speeds were obtained for one wheel.

The average wheel wear for each wheel speed at the various diameters was as follows:

Diameter of wheel, inches	Speed in surface feet per minute	Wheel wear, inches	Size of machine, inches capacity
13	4765	0.0095	10 x 50
11	4030	0.0120	10 x 50
11	5752	0.0085	10 x 50
11	5100	0.0085	6 x 32
11	6900	0.0065	6 x 32
8½	5100	0.0115	6 x 32

The effect of wheel speed is evident in the foregoing. The change in speed of the 11-inch wheel shows a decrease in wheel wear with increase of speed. These values are shown graphically in Fig. 10.

Regarding the change in the wheel diameter, it will be noted

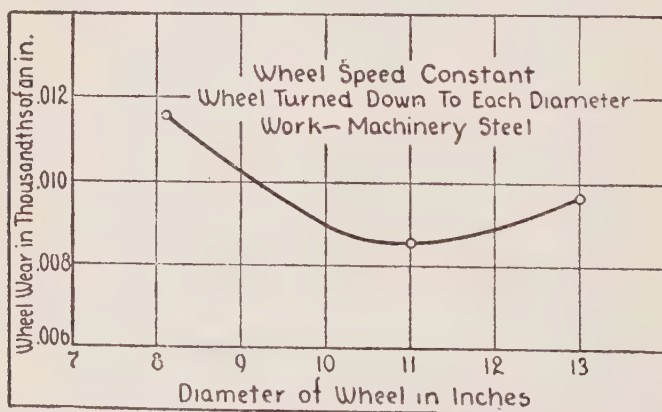


FIG. 9—EFFECT OF A CONSTANT WHEEL SPEED WITH THE WHEEL TRUED TO THE DIAMETERS GIVEN

that at the same approximate surface speed the difference between the 13 and 8½-inch wheels is quite noticeable. These values are graphically shown in Fig. 9, where change in diameter is plotted against variation in wheel wear. The point in the curve, to blend in thoroughly with the grain depth of cut

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theory, for the 11-inch wheel, should occupy a place lower than the 8½-inch wheel and yet higher than the 13-inch wheel. The low point in the curve at the 11-inch diameter may substantiate, however, to some degree the vaguely expressed thought by a few observers that for a given piece of work there is an optimum wheel diameter, other factors being in harmony.

The foregoing results serve to verify the following theoretical conclusions: Other factors remaining constant, increase of wheel speed decreases grain depth of cut and makes a wheel

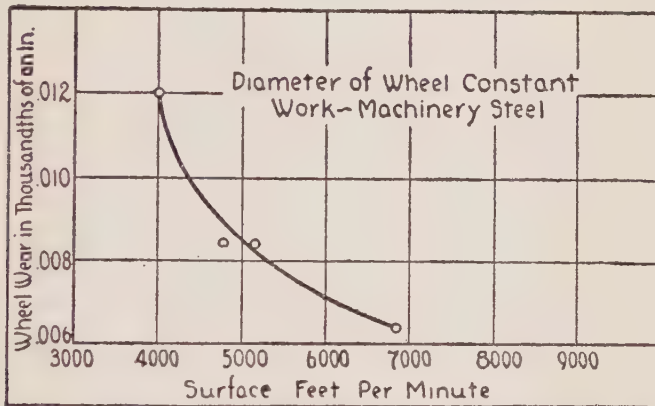


FIG. 10—EFFECT OF A CONSTANT WHEEL DIAMETER WITH THE WHEEL OPERATED AT VARIOUS SPEEDS

appear harder. Other factors remaining constant, diminishing the diameter of the grinding wheel increases grain depth of cut and makes a wheel appear softer. The foregoing constitutes a comprehensive report on a grinding wheel test to prove the grain depth of cut theory and it offers an excellent example of an outline to follow in reporting tests.

ERROR IN GRINDING

According to the Brown & Sharpe Mfg. Co., it is easy to be deceived as to the amount of error in roundness when judging by the sparks from the wheel. For example, a piece of work 36 inches long and 3½ inches in diameter when in process of grinding showed sparks from one side only. Without correcting the error, the piece was measured with a micrometer. The error was so slight that it could not be detected and an indicator held against it while revolving showed no motion. Another

experiment was conducted with a hardened steel plug, 1 inch in diameter. It first was ground round and straight, then carefully measured, replaced in the machine and the wheel advanced until sparks were just visible. When this amount was ground away the work was again measured and found to have been reduced in diameter about one hundredth part of one thousandth of an inch. The accuracy of work, therefore, must be very great when with a suitable wheel and plenty of lubricant, a long piece can be ground showing sparks over its entire circumference and with such a light cut that they are barely visible.

ESTIMATING GRINDER PRODUCTION

Attempts to estimate the production of a cylindrical grinding machine on a speed and feed basis, according to R. E. W. Harrison, never have been satisfactory as the ratio of metal removed is not constant throughout the operation, but is variable at the start and finish of the job. This is shown in Fig. 11. A parallel spindle 10 feet long and 1½ inches in diameter can be considered as an example. With no variable present, a grinding machine working from rough stock could reduce the material at the rate of two cubic inches per minute. The job under these conditions would be completed in 20 minutes if the shaft

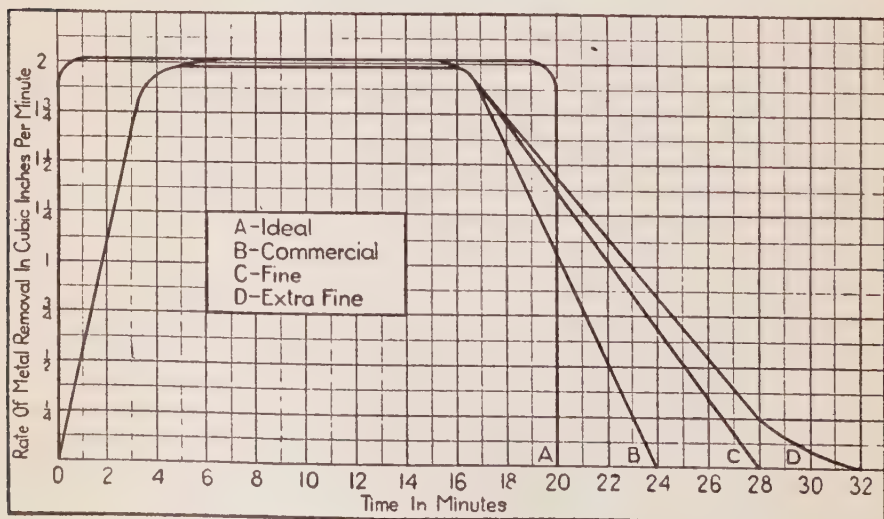


FIG. 11—FACTORS INFLUENCING GRINDER PRODUCTION

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were ground from stock $1\frac{5}{8}$ inches in diameter. In actuality, however, the wheel cuts slowly during the few first minutes of the operation as it is working on eccentric stock to some extent. The scale on the stock also slows down the procedure appreciably. When the shaft becomes an approximate true cylinder, the operation can be carried out at the maximum producing capacity of the machine. When the finish size is approached, say within 0.002 to 0.003-inch, the degree of finish and the accuracy required will slow down the operation. The foregoing chart gives the approximate grinding time for ideal commercial fine and extra finishes.

FORM GRINDING

Form grinding was developed many years ago during the early days of the bicycle industry when formed wheels were used successfully for finishing ball bearing cups and cones. Another practice developed many years ago consisted for forming marble balusters with contour wheels. During the early days of the automobile industry wheels with formed corners were introduced for finishing automotive engine crankshaft bearings. This marked the first step in modern form grinding. Today formed wheels are used for a diversity of purposes. Perhaps the most practical consists of generating tapers on such parts as drill shanks and automobile rear axle ends. In the strictest sense of the work word, this may be classed under plunge-cut grinding. However, since the taper is a form, perhaps the term form grinding is practicable. The shapes generated in form grinding must be continuous and uniform for it is obvious that sharp corners or undercuts cannot be made. The wheel face must be shaped accurately by a diamond governed by a template or master cam to generate the desired contour. A limitation in form grinding is the depth of the "valleys" for it is obvious that if they are very deep the wheel face will have a number of peripheral speeds which is not conducive of good work.

In considering the ordinary run of work finished by form grinding, however, pieces with deep depressions are the exception and not the rule, so that the factor of work speed is not a serious detriment although experimentation often is necessary. As a general rule the wheel must be hard enough to hold its corners and the work speed adjusted accordingly.

FORMULAS FOR GRINDING

The following formulas for grinding were compiled by Robert J. Spence. The necessary grinding data is given in Fig. 12.

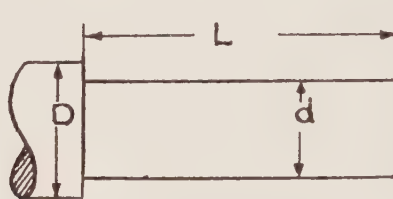


FIG. 12—GRINDING DATA

D = Rough diameter.

d = Finish diameter.

L = Length of portion to be ground.

N = Number of revolutions per minute (R. P. M.)

T = Time of cut.

$$M = \text{Mean diameter} = \frac{D + d}{2}$$

$$C = \text{Depth of cut} = \frac{D - d}{2}$$

$$\pi = 3.1416 \text{ or } \frac{22}{7} \text{ approximately}$$

All dimensions are to be measured in inches.

Formula No. 1 is for finding stock removed per minute in cubic inches.

$$\frac{\pi D^2 L}{4T} - \frac{\pi d^2 l}{4T} = \frac{\pi L}{4T} (D^2 - d^2)$$

Problem, to find cubic inches of stock removed per minute.

Example:

D = 2.1 inches, d = 2 inches, L = 10 inches, N = 100, T = 4 minutes, C = .050 inches, M = 2.050 inches.

Solution from formula:

$$3.1416 \times 10 \text{ inches} = 31.416$$

$$4 \times 4 \text{ minutes} = 16$$

$$31.416 \div 16 = 1.963$$

$$2.1 \times 2.1 = 4.41$$

$$2 \times 2 = 4$$

$$4.41 - 4 = .410$$

$$1.963 \times .410 \text{ inches} = 0.805 \text{ cubic inches per minute.}$$

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Formula No. 2 for finding stock removed per minute in cubic inches.

$$\frac{\pi M L C}{T}$$

T

Problem, same as the foregoing. Solution from formula:

$$3.1416 \times 2.050 = 6.44$$

$$6.44 \times 10 = 64.4$$

$$64.4 \times .050 = 3.22$$

$$3.22 \div 4 = 0.805 \text{ cubic inches per minute.}$$

Formula for finding the approximate amount of stock removed per minute, using 22 as π ;

$$\frac{22}{7}$$

$$\frac{\pi L D C}{T}$$

T

Problem same as preceding. Solution from formula.

$$22 \times 10 \text{ inches} \times 2.1 \text{ inches} \times .050$$

$$\frac{\quad}{7 \times 4 \text{ min.}} = .825 \text{ cubic inches per minute.}$$

Formula No. 1 for finding the cutting speed or work surface speed.

$$\frac{N M \pi}{12}$$

12

Problem: To find the cutting speed of a piece of work of the dimensions given above:

Example:

$$N = 100 \text{ R. P. M., } M = 2.050 \text{ inches.}$$

Solution:

$$100 \times 2.050 \times 3.1416 = 644$$

$$644 \div 12 = 54 \text{ feet cutting speed.}$$

Formula No. 2 for finding the cutting speed or work surface speed.

$$N (D + d) \times .131$$

Example:

$N = 100$ R. P. M. $D = 2.100$ inches $d = 2$ inches.

Solution:

$$D + d = 4.100 \text{ inches}$$

$$100 \times 4.100 \times .131 = 54 \text{ feet, cutting speed.}$$

Formula No. 3:

$$N \times M \times .262$$

Problem: Same as above.

Solution:

$$100 \times 2.050 \text{ inches} \times 0.262 = 54 \text{ feet cutting speed.}$$

Table traverse is most often expressed in inches per minute.

Formula:

$$N \times \text{overlap of wheel face in inches.}$$

Problem: Find the table traverse of a machine grinding the piece of work in the preceding example.

Example:

$N = 54$, 2 inches = advance of table per revolution of work.

Solution:

$$54 \times 2 \text{ inches} = 108 \text{ inches table traverse per minute.}$$

Formula to use in calculating when to change to small spindle-pulley on Norton plain grinding machines:

Problem: To calculate (when a grinding wheel has become worn to a smaller diameter) the correct diameter at which to change from the large spindle-pulley to the small spindle-pulley so as to again bring the surface speed on the wheel periphery to 6500 feet.

Let D = diameter of wheel, full size.

Let d = diameter of wheel, reduced size.

Let S = diameter of large size spindle-pulley.

Let s = diameter of small size spindle-pulley.

Let N = R.P.M. of spindle, using large pulley.

Let n = R.P.M. of spindle, using small pulley.

Formula:

$$\frac{SN}{s} = n$$

and

$$\frac{DN}{n} = d$$

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Example:

The wheel on a 6-inch Norton plain grinding machine has become worn to a diameter of 10 inches. Is it safe to change the spindle-belt on to the small diameter spindle-pulley?

Solution:

The R.P.M. of the spindle with the belt on the large spindle-pulley is 1773. A new grinding wheel of 14-inch diameter has a surface speed of 6500 feet. The large spindle-pulley is 5½-inch diameter and the small spindle-pulley is 4 inches.

Then by formula:

$$\frac{5.5 \text{ inches} \times 1773 \text{ R.P.M.}}{4 \text{ inches and } 14 \text{ inches} \times 1773 \text{ R.P.M.}} = \frac{2438}{2438}$$

10 3/16-inch diameter of reduced size wheel at which to change from large to small spindle-pulley to again obtain a surface speed of 6500 feet.

The following data pertains to Norton grinding machines with 3, 6, 10 and 14-inch swings.

A	B	C	D	E	F	G
3	4	2½	2,485	3,976	10	6¼
6	5½	4	1,773	2,438	14	10 3/8
10	7¾	6½	1,380	1,645	18	15¼
14	9	7½	1,241	1,493	20	16¾

A—Size of machine, swing in inches.

B—Diameter of large spindle pulley, inches.

C—Diameter of small spindle pulley, inches.

D—Spindle speed, R. P. M., with belt on large spindle pulley.

E—Spindle speed, R. P. M., with belt on small spindle pulley.

F—Diameter of grinding wheel, when new, inches.

G—Diameter of grinding wheel, inches, with belt on small spindle pulley to obtain 6500 feet per minute surface speed.

MULTIPLE WHEEL GRINDING

The so-called multiple wheel method of grinding consists of mounting two or more wheels on one arbor with the object of finishing more than one surface in a given operation. Thus in Fig. 13 two wheels are arranged to grind two different diam-

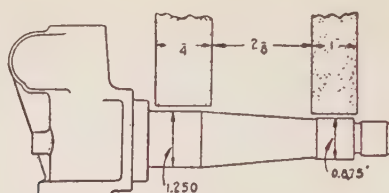


FIG. 13—GRINDING TWO SURFACES
AT ONE SETTING OF THE WORK

eters on a steering knuckle. In many instances, multiple wheel grinding doubles the output of the machine and releases the operator for other work. For the purpose of comparing the old and the new methods the following data are given:

Machine cost	\$2,000.00
Hourly wage	.60
Hourly overhead	.90
Yearly depreciation, per cent.....	10
Interest in investment, per cent.....	6

The results of a four week's comparison of the single and multiple wheel method of grinding are given:

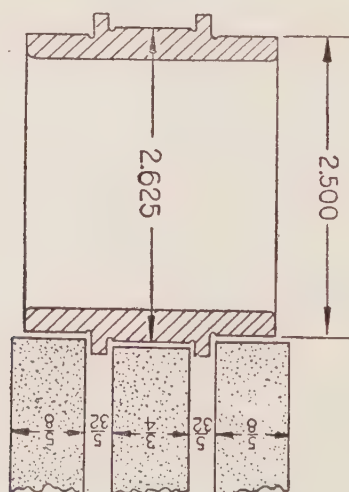


FIG. 14—FINISHING THREE SURFACES
AT ONCE

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OLD METHOD—TWO MACHINES

Wages	\$240.00
Overhead	360.00
Interest, etc.	49.25
Total	\$649.25

NEW METHOD—ONE MACHINE

Wages	\$120.00
Overhead	180.00
Interest, etc.	24.62
Total	324.62

In the production of the steering knuckles illustrated above an average of 80 per hour were ground, removing 0.015-inch of material with a tolerance limit of 0.0005-inch. In the example shown in Fig. 14 three surfaces are ground simultaneously on a steel bushing. The illustration is self explanatory.

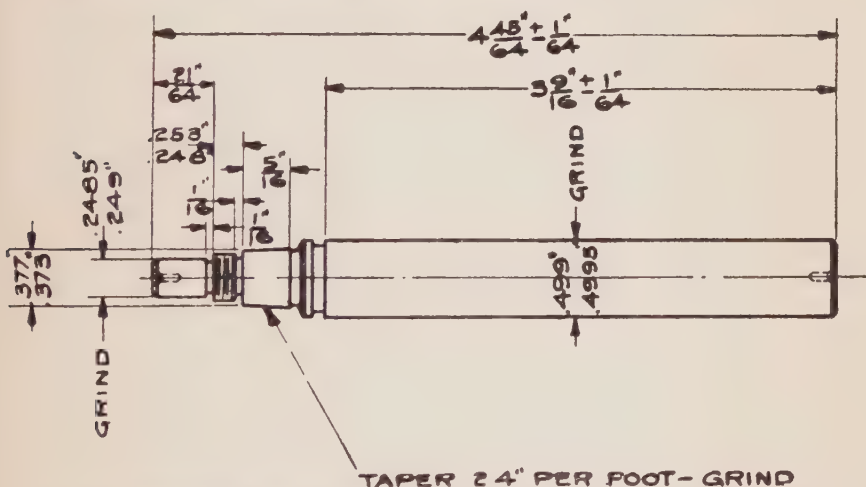


FIG. 15—REPRESENTATIVE PART THAT CAN BE FINISHED READILY BY MULTIPLE-WHEEL GRINDING

Another part that successfully combines the grinding of a taper and a straight diameter is shown in Fig. 15. The straight diameter is 0.249-inch, $+ 0.000$, and $- 0.0005$ -inch, $\frac{1}{4}$ -inch long, and the taper is $\frac{5}{16}$ -inch long and is held to a tolerance of $+ \text{ or } - 0.010$ -inch from surface A. This part was originally ground on two machines which produced 118 shafts per hour. This grinding is now done on a 6×32 -inch Norton type A belt drive machine mounting two $14 \times \frac{7}{16} \times 5$ -inch, 6624 combination grit, M grade, vitrified aluminum oxide running at 1370 revo-

lutions per minute. A work speed of 250 revolutions per minute is used. Production by the twin wheel method is 200 shafts per hour removing 0.015-inch of stock. For truing the wheels used on the distributor shaft a wheel forming device is used instead of the multistop index. This device includes a form bar which is made so that the shapes trued on the wheels bear the correct relation to each other. To further facilitate this truing operation the wheel truing device mounted on the wheel guard has been developed. The path of the diamond is governed by a forming bar. The diamond is traversed across the wheels by an electric motor mounted on the rear of the guard. Another novel feature of this attachment is that the water is directed upon the wheels inside of the guard. This does away with much of the spray ordinarily present.

Various parts have been ground by this twin wheel method but latest developments indicate that this method of grinding can be applied to crankshafts. Production men in general will be interested in the results obtained in grinding the center pair of pins of the Ford crankshaft. The machine is a regular Norton type B crankpin grinding machine with the pot chuck equipment regularly made for single wheel grinding. A special wheel guard and wheel sleeve on which are mounted two wheels with spacing collar between to give the correct dimension are required.

Experience in grinding these shafts recommends a pair of $26 \times 1\frac{1}{2} \times 12$ -inch vitrified aluminum oxide wheels running at approximately 6500 surface feet per minute. The work is rotated at about 98 revolutions per minute. Finish grinding, removing 0.050-inch of stock on the diameter, was accomplished in 50 seconds actual time or $1\frac{1}{2}$ minutes per shaft including handling. The limits held were standard to 0.002-inch minus. Only one two-bearing steadyrest, located opposite the outer wheel, is required. An indicating gage is mounted on the wheel guard and measures the inner pin. The twin wheels hold size very well, averaging 30 to 35 shafts per dressing. Previous practice using a single wheel moving from one pin to the other finish grinds 22 shafts per hour on the inner pins or 2.7 minutes per shaft. This shows an increase in production per machine of about 80 per cent.

The machine is equipped with regular wheel feed, but for this grinding operation a lever feed is used that moves the wheel

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back about $\frac{3}{4}$ -inch in an 80 degree movement of the lever. This fast movement of the wheel slide gives the extra clearance necessary for the rapid handling required in high production.

PLUNGE-CUT GRINDING

A term applied to grinding when the work is fed directly to the wheel without traversing. The practice originated some years ago in roughing out work. Today it is used extensively for both the rough and finish grinding of parts. The width of wheel is limited at the present time to approximately 12 inches. Plunge-cut grinding cannot be carried out successfully on machines of frail construction as chattering would result. Special machines have been designed for this purpose. They are used extensively in automobile manufacturing plants.

RIBBON GRINDING

This is a term used to describe an abnormal grinding method discovered by accident many years ago. In the operation of a cylindrical grinding machine, if the work speed is very slow and the depth of cut deep, the metal leaves the work in the form of a ribbon-like chip as wide as the wheel face. This phenomenon has been investigated thoroughly and results of careful tests have shown that when the power required for driving, together with the abnormal wheel wear are considered, the method is not productive of economical results.

SIZING OF WORK

Grinding machines are equipped with automatic cross feeds and appliances for throwing out the feed when the desired diameter is reached. It is the usual procedure to set the appliance after one or two pieces have been ground. By this means the work will not be finished undersize as wheel wear results in making the work oversize. Thus it must be corrected by setting the wheel in from time to time. Grinding gages are very handy to use in sizing work as they show the operator the progress of grinding at all times. Care should be exercised in handling these gages as they are sensitive instruments. With due care they last indefinitely and they can be depended on to give good results. They are used extensively where large runs of production work are made.

TAPER GRINDING

Aside from the taper grinding operations explained under the heading of universal grinding the plain grinder can be used for finishing external tapers within certain limitations. The work is held between centers in the usual way and the taper derived by setting over the swivel platen. The amount the platen can be set over determines the taper that can be ground. Tapers also are ground by the wide wheel or plunge-cut method. In this case the wheel can be provided with a taper face by means of a special truing device, or the wheel face can be straight and the swivel platen set over.

TRAVERSE FEED

A term used in cylindrical grinding practice to refer to the longitudinal progress of the work in relation to its rotation. In roughing operations the work should traverse very nearly the width of the wheel for each work revolution. Thus if a wheel with a $2\frac{1}{2}$ -inch face is used, the work should traverse for each of its revolutions about $2\frac{1}{4}$ inches. It is understood that heavy, rigid machines are necessary to take advantage of wide traverse feeds. In finishing operations, the traverse feed is stepped down somewhat so that the work advances from $\frac{1}{4}$ to $\frac{1}{2}$ of the width of the wheel face for each work revolution.

UNEVEN SPARKING

In cylindrical grinding operations, especially when roughing out work, it often is noted that the wheel suddenly begins to spark heavily and unevenly. This is not the fault of the machine as it is generally caused by the internal strains in the work adjusting themselves as stock is removed. This condition corrects itself automatically. All that is necessary is to proceed to grind without further cross feeding until the work sparks very slightly. Then the work can be fed in again a slight amount. One or two cuts probably will be sufficient to bring the work round again. An error of less than 0.0001-inch will cause the wheel to spark unevenly. Dirt in the centers also is a cause of uneven sparking. The remedy is to clean out the centers before the work is mounted in the machine.

CYLINDRICAL GRINDING

UNIVERSAL GRINDING PRACTICE

Universal grinders are used on both tool-room and production work. The following examples show how such machines can be arranged to handle a number of interesting operations. These illustrations were furnished by the Brown & Sharpe Mfg. Co. When finishing ordinary cylindrical work, the operation of the machine does not differ from that of a plain grinder; that is, the work usually is dogged on one end and rotated between

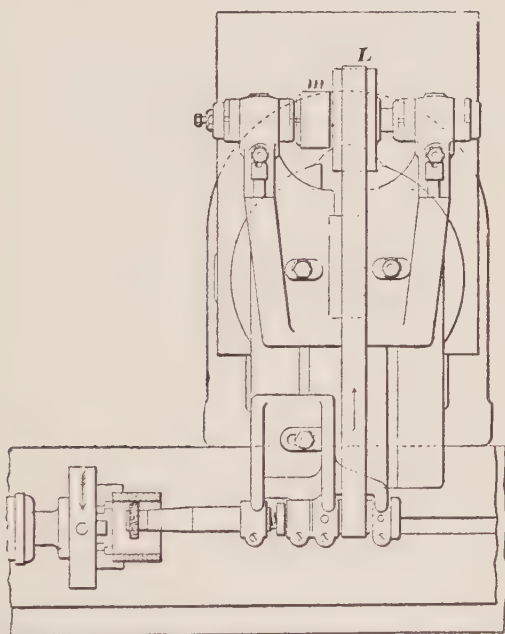


FIG. 16—UNIVERSAL GRINDER ARRANGED FOR INTERNAL WORK

dead centers. The headstock swivel base is set so that the work spindle is in line with the platen travel and the machine is set to grind the work straight by setting over the upper or swivel platen. On first thought, it would appear that if the graduations on the headstock base and those on the swivel platen were set at zero, the machine should grind straight without further adjustment. This is true in theory but in actual practice it does not work out as a slight amount of dirt under the head or tailstock will alter the setting. Any toolmaker knows that if the

tailstock of an engine lathe is moved, it will not turn straight work without resetting and the same holds true with a grinding machine.

Fig. 16 shows how the machine is arranged for internal grinding. The wheel platen is reversed, the wheel spindle removed and the countershaft, *L*, is substituted. The internal grinding fixture is bolted to the front of the wheel platen. The

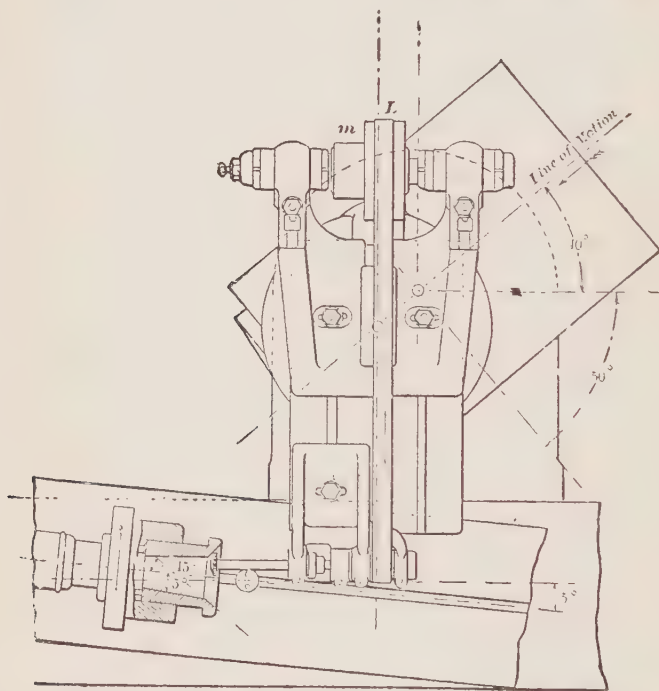


FIG. 17—INTERNAL GRINDING OF TWO ANGLES AT ONE SETTING

belts should run in the same direction and the wheel spindle and work should rotate as shown by the arrows. The countershaft, *L*, is driven from the overhead countershaft by a belt on the pulley, *M*. An interesting job on internal grinding where two angles are generated at one setting of the work is shown in Fig. 17. The swivel platen is set over five degrees which generates a 10-degree included angle in the body of the piece. The 45-degree angle is obtained by setting the wheel platen over 40 degrees which with the five degrees overset on the swivel platen generates the necessary angle. The "line of motion" in

the illustration can be set to include any angle from 0 to 90 degrees. It is a valuable feature of the universal grinding machine and one that always is not utilized to the fullest extent. In general, the work is held in a chuck screwed to the spindle

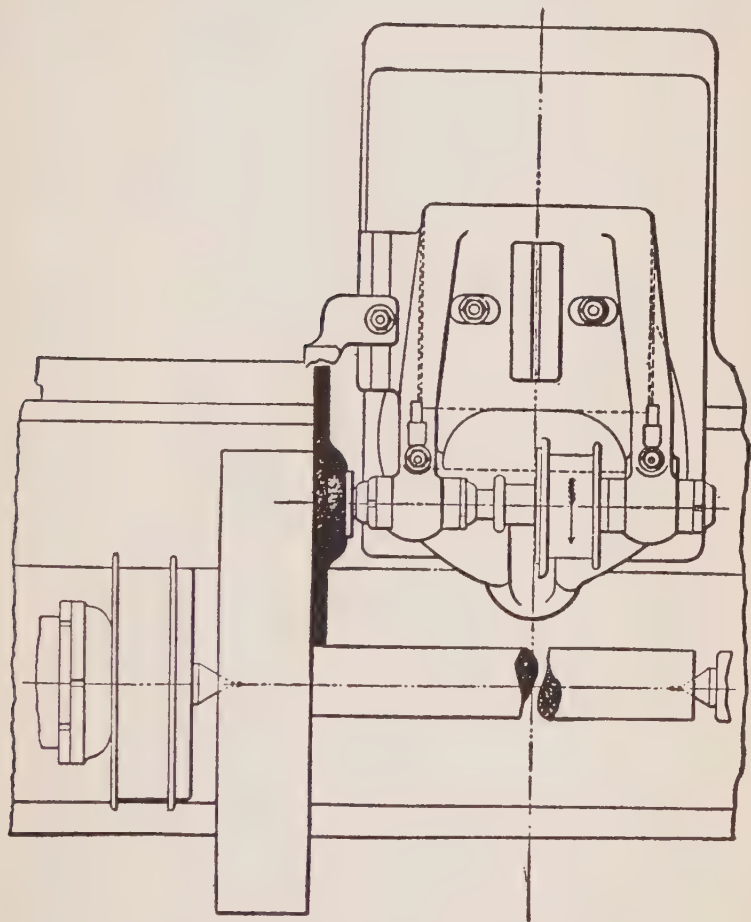


FIG. 18—FACE GRINDING ON A UNIVERSAL MACHINE

nose when performing internal grinding on a universal machine, although there is no reason why the fixtures used for internal grinding cannot be used on a universal machine, should necessity warrant. On Fig. 18 is shown a universal machine arranged to finish the side of a piece. Such an operation consists of face grinding work that is held between centers. It is accom-

plished by locating a special shape wheel on the end of the spindle so that the wheel face can be fed past the face of the work by the cross feed. The wheel mounted on the end of the spindle is handy for a number of special grinding operations.

How the grinder is arranged for finishing an external taper is shown in Fig. 19. The work in this case is held between

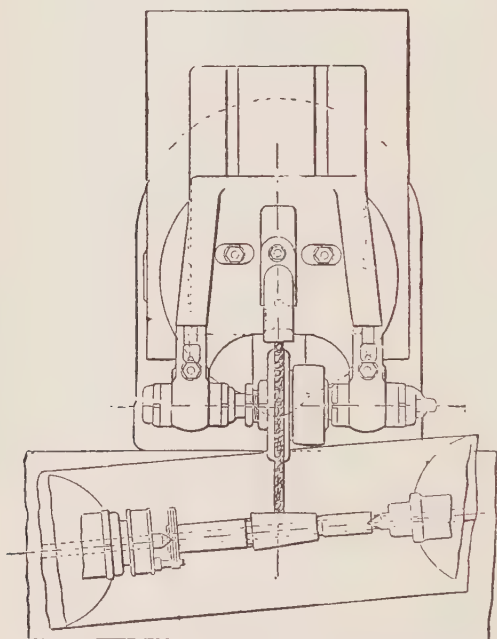


FIG. 19—SWIVEL TABLE SET OVER FOR GRINDING AN EXTERNAL TAPER

centers and driven by a dog from the face plate. The degree of taper is obtained by setting over the swivel platen. In Fig. 20 is shown the machine arranged to grind an abrupt taper. In this case it is necessary to set the wheel platen over, as the illustration shows, to generate the desired angle on the work. The machine arranged for grinding two external tapers at one setting is shown in Fig. 21. As in the example of internal grinding previously cited, the swivel platen and the wheel platen both are set over to generate the necessary angles. A recessed wheel is used sometimes for facing work as shown in Fig. 22.

In this case the part to be finished consists of a steel bushing. It is located on an arbor in the usual way and the grinding is performed by utilizing the side of the wheel. Centers on universal grinding machines are ground, as shown in Fig. 23, by setting the headstock swivel over to an angle of 30 degrees.

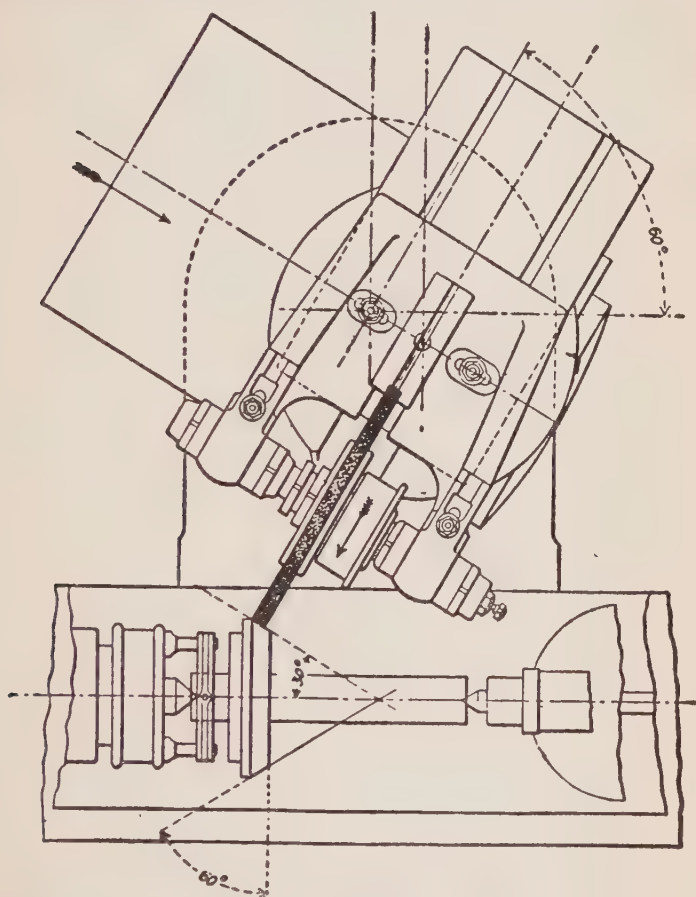


FIG. 20—GRINDING AN ABRUPT TAPER BY SETTING OVER THE WHEEL STAND

Various other angular jobs can, of course, be performed in the same manner by using special fixtures for locating and driving the work.

By setting the spindle of the headstock at an angle of 90 degrees with the platen, as shown in Fig. 24, various face grinding operations can be performed. In this case the work

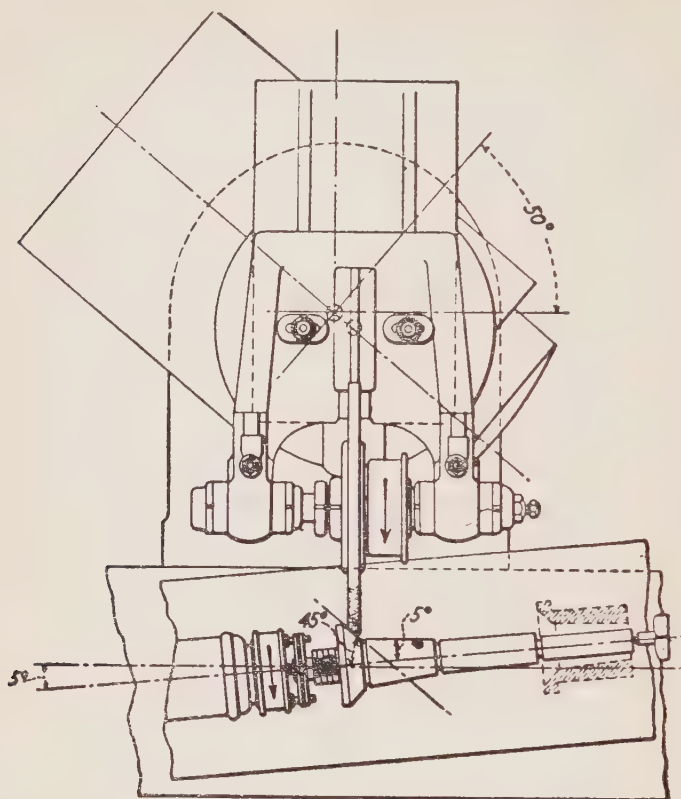


FIG. 21—FINISHING TWO EXTERNAL TAPERS AT ONE SETTING

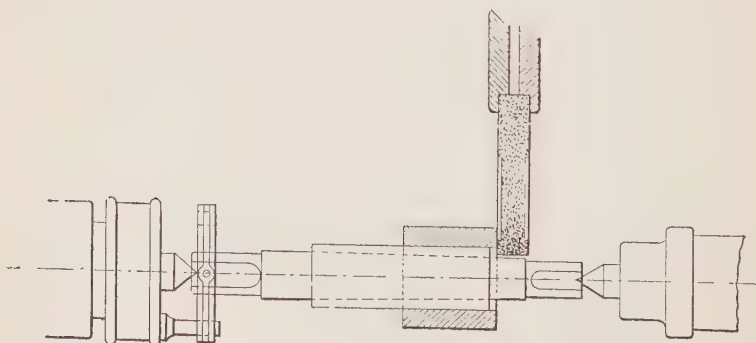


FIG. 22—SQUARING THE ENDS OF A BUSHING WITH THE WHEEL FACE

CYLINDRICAL GRINDING

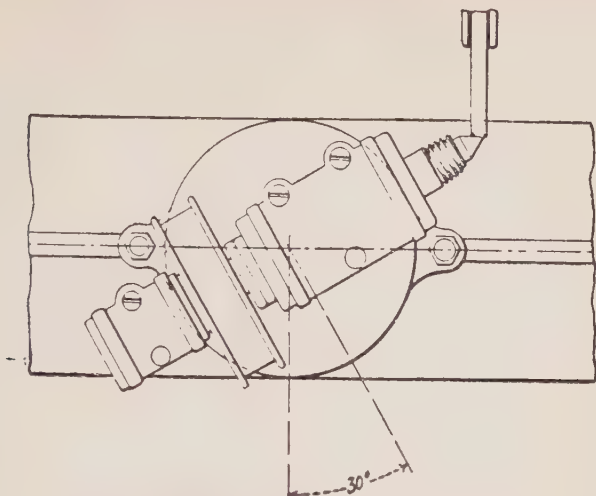


FIG. 23—GRINDING CENTERS BY SETTING THE HEADSTOCK OVER

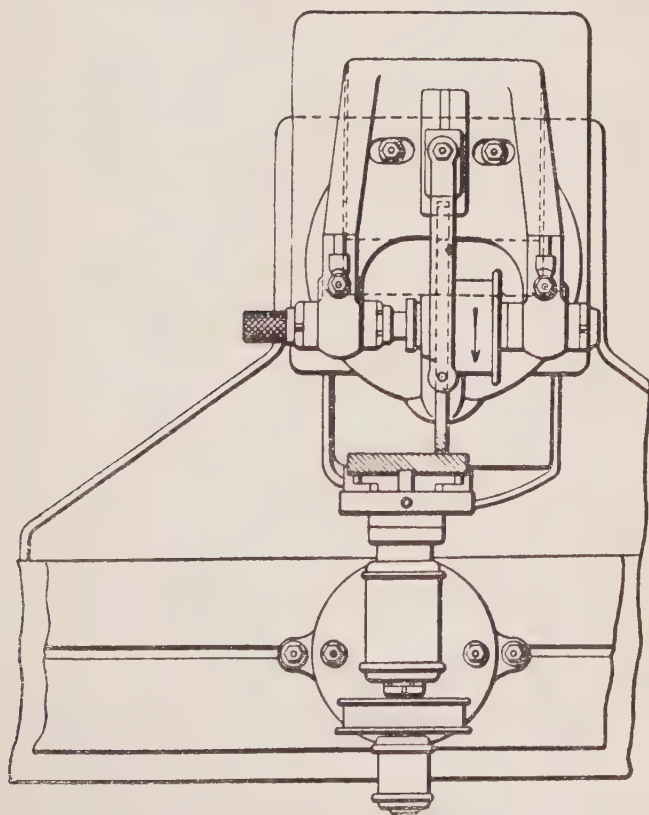


FIG. 24—FINISHING THE FACE OF A PIECE ON A UNIVERSAL MACHINE

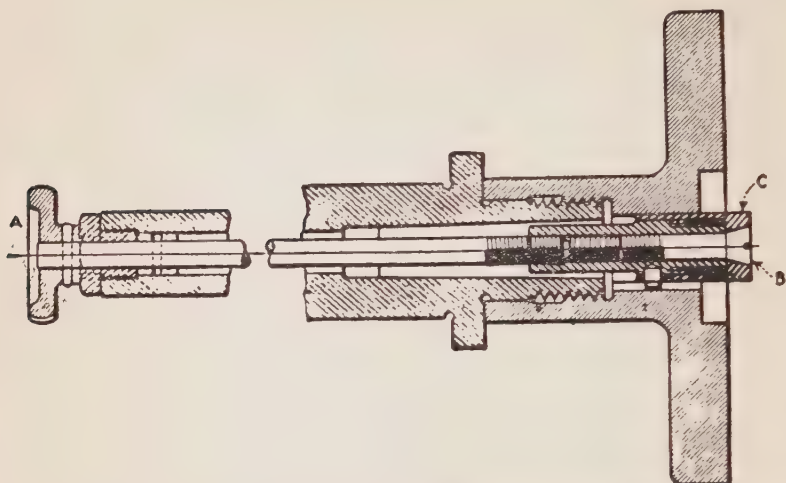


FIG. 25—DETAILS OF DEVICE FOR HOLDING WORK FOR FACE GRINDING

is located in a 4-jaw chuck screwed to the spindle nose. For handling various jobs of face grinding, cutters, disks, etc., the appliance shown in Fig. 25 can be used to advantage. It fits the headstock spindle and consists of an expanding bushing, *C*, which is expanded by the member, *B*. This part is drawn back by turning the handwheel, *A*. The work locates against the face plate. The universal grinder can also be utilized for a diversity of milling cutter sharpening operations. For convenience, the smaller size grinders generally are used. On Fig. 26 is shown how an ordinary milling cutter is arranged for sharpening. It can be held on an arbor between centers, or on a stub arbor held in the headstock spindle. A wheel is located on the spindle and the guiding finger set under it. Further data on cutter sharpening are given in Section VIII. Another type of

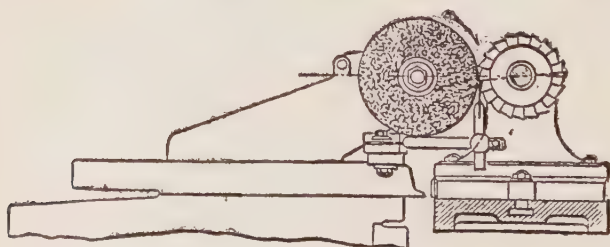


FIG. 26—SHARPENING A MILLING CUTTER ON A UNIVERSAL GRINDER

CYLINDRICAL GRINDING

universal grinding machine, sometimes called a full universal grinder, aside from performing the operations here cited can be arranged for surface grinding also. This is accomplished by locating the grinding wheel spindle at right angles with the platen and providing means for raising and lowering the wheel to control the depth of cut.

USE OF BACKRESTS

Backrests should be used on cylindrical grinding machines in grinding long, comparatively slender pieces. A good rule is to use one backrest to each foot of work on approximately one inch in diameter. The object of using backrests is, of course, to overcome chattering by reducing vibration. Backrests are of two general types, plain and universal. A plain backrest has no spring action to keep the dogs in contact with the work, while a universal one is equipped with these members. In locating the backrest, it is a good plan to feed in the wheel, adjusting the dogs or shoes at the same time. By taking a light finishing cut the work can be brought round in this manner. Once supported by one or more backrests, deep cuts can be taken which would be impossible were the work free from center to center. Backrest shoes are wood, bronze, hard steel, etc. The kind of material to select often is a matter of some judgment. Of hard steel it can be said that it will not fill with chips that cause scratches. Bronze is a favorite material as it does not scratch the work, while wood also is preferred for the same reason.

USE OF LUBRICANT

Use plenty of cooling solution when operating a plain or universal grinding machine. This applies particularly to production grinding. The type to use is a matter of judgment in many cases. It should be delivered to the work in a copious stream over the point of grinding contact.

WIDE WHEEL GRINDING

This is another term applied to plunge cut grinding and sometimes to form grinding. It is used extensively in the automobile manufacturing industry.

WORK-LOCATING DEVICES

In general cylindrical grinding practice, the work is located between two dead centers and is driven by a dog clamped on one end. Under ordinary conditions, this method is productive of good results if the piece is of such shape that two finished diam-

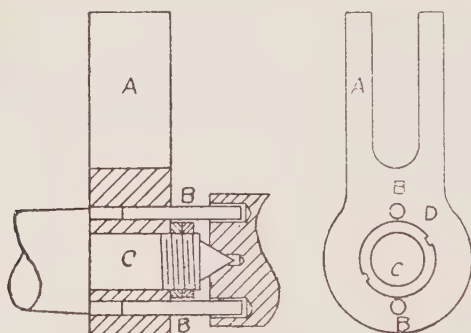


FIG. 27—WORK DRIVING DEVICE

eters are desired, or if the dog can be placed over a section that does not require grinding. Often, however, it is necessary to grind one diameter on the entire length of the piece. Under these conditions, the ordinary dog is not productive of efficient

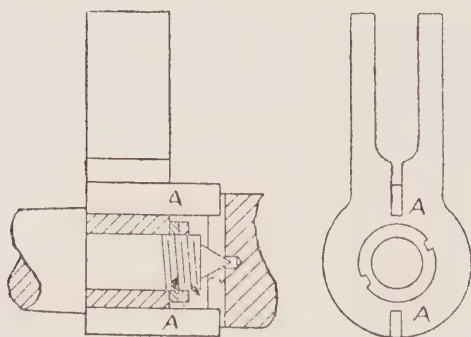


FIG. 28—ANOTHER SIMPLE WORK DRIVER

results as the piece has to be dogged twice during the grinding operation. This results in a loss of time and under some conditions in the production of inaccurate work.

In grinding work of one diameter only, excellent results can be derived with the work driving device illustrated in Fig. 27. This appliance embodies a slotted driver, A, that is actuated

by the drive pin on the headstock face plate. Two pins, *B*, fit holes in the end of the work, while the driver rotates over a special dead center, *C*. It locates against a shoulder at one end, while two check nuts, *D*, take up the end play and keep it

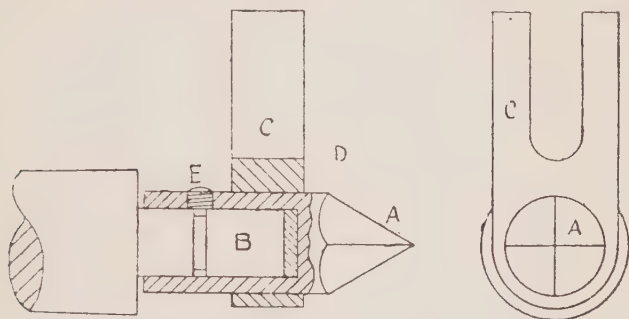


FIG. 29—SQUARE CENTER FOR DRIVING WORK

in place. When it is necessary to regrind the center, the two pins, *B*, should be driven in so that they will not bottom in the holes in the work before the center in the piece brings up against the grinder center.

Another device operating on a similar principle also is shown in Fig. 28. In this case the work is slotted at one end

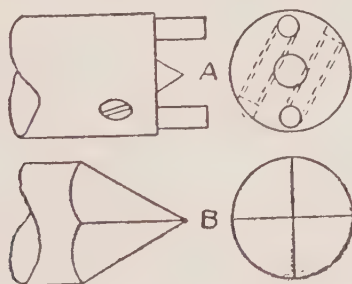


FIG. 30—LIVE DRIVING CENTERS

to accommodate the steel projections, *A*. The square centers shown in Fig. 29 also are used extensively. In using this device it is, of course, necessary to broach square the center hole in the work to accommodate the square center. This operation is performed readily with a hand-driven broach or under a power press. The square center, *A*, fits over a special center, *B*, and is rotated by the driver, *C*, which, in turn, is driven by the

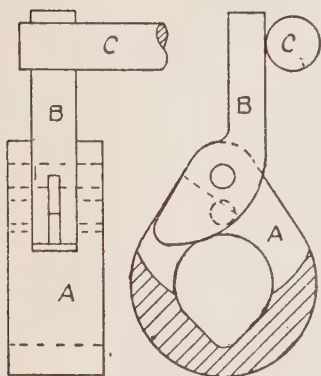


FIG. 31—QUICK-ACTING DOG

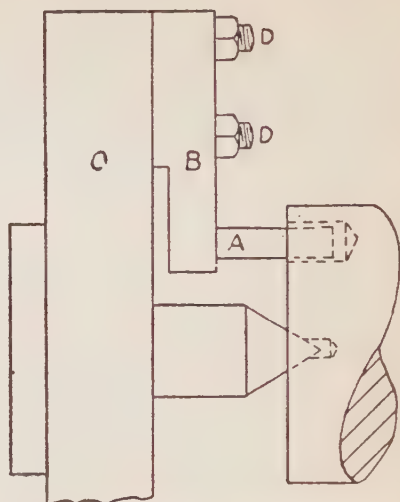


FIG. 32—DRIVER FOR LARGE WORK

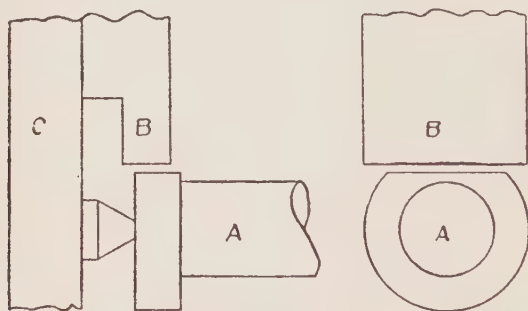


FIG. 33—SPECIAL DRIVER FOR A STUD

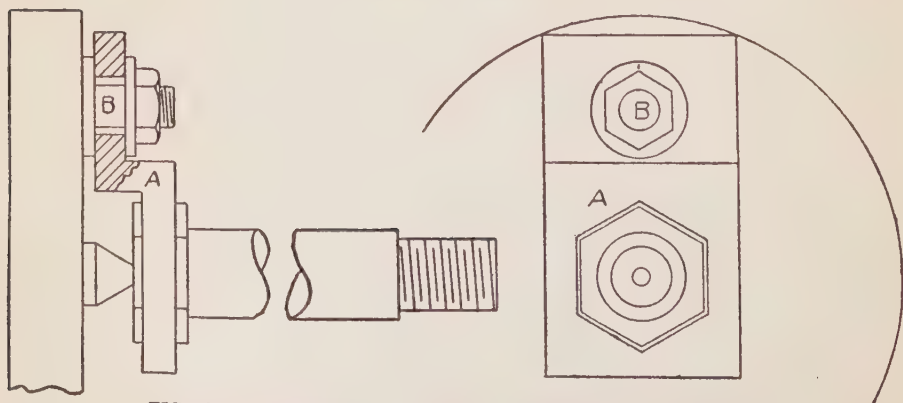


FIG. 34—DRIVER FOR HOLDING HEXAGON-HEAD STUDS

CYLINDRICAL GRINDING

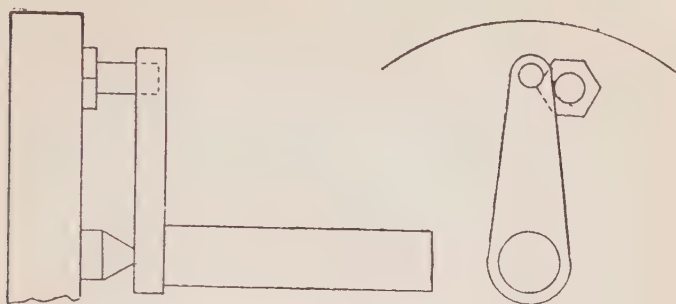


FIG. 35—UTILIZING THE DESIGN OF A PART FOR DRIVING

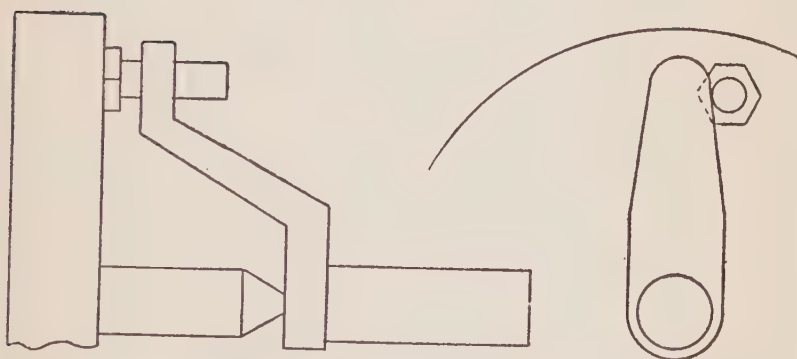


FIG. 36—A LONG CENTER ACCOMMODATES THIS OFFSET LEVER



FIG. 37—FEMALE GRINDING CENTERS

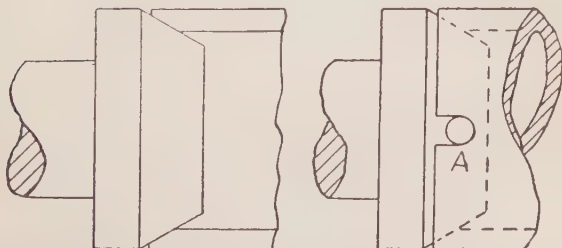


FIG. 38—SPECIAL CENTERS ARE USED FOR GRINDING TUBING

face-plate pin. End thrust is taken care of by the fiber washer, *D*, while the screw, *E*, fits in a groove to prevent the device from coming apart. A center of this kind must be made accurately and the internal diameter of the hollow center, *A*, and the external part of the center, *B*, should be finished by grinding to insure a good fit. If the parts fit loosely it is evident that accurate work cannot be ground. If the parts are hardened and finished by grinding, however, the arrangement will give good results.

Two driving centers of another type also are illustrated. The upper illustration, *A*, Fig. 30, is a live center equipped with

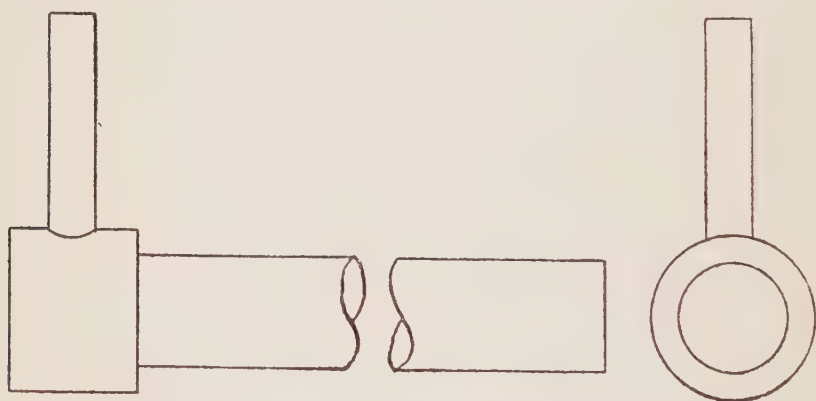


FIG. 30—ARBOR WITH A DRIVER FOR FINISHING BUSHINGS

two adjustable pins held in place with set screws put in from opposite sides. These pins fit holes drilled in the end of the work. A square live center is shown at *B*. These devices accomplish the desired results, but in using them it is necessary to rotate the headstock spindle which results in unnecessary wear. Again, such devices can be used only on universal grinding machines as the ordinary headstock on the plain grinder is not equipped with a rotating spindle.

The quick-acting dog shown in Fig. 31 was designed to reduce the time necessary to locate an ordinary driving dog in place. It embodies a body, *A*, and a clamping member, *B*, that is driven by the face-plate pin, *C*. The tail of the clamping member is eccentric with its fulcrum so that when pressure is brought against it by the driving pin, the lower end of the clamp

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bears against the work with sufficient pressure to rotate it positively.

The clamp is tool steel, spring tempered, while the body is machinery steel, case-hardened. The clamp tail is split and before it is tempered, the ends are spread apart slightly. Thus this member always is a snug fit in the body. This is necessary

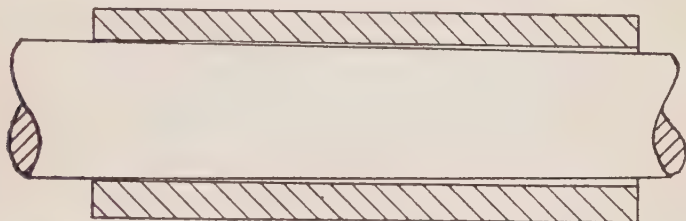


FIG. 40—HOW A TAPER ARBOR DISTORTS WORK IN GRINDING

to hold it in position against the work before pressure is brought to bear by the action of the driving pin. The body, A, is provided with two fulcrum pin holes so that by moving the clamp from one to another, several sizes of work can be accommodated.

When grinding large work, say $2\frac{1}{2}$ inches in diameter and over, the piece can be driven as indicated in Fig. 32. As the

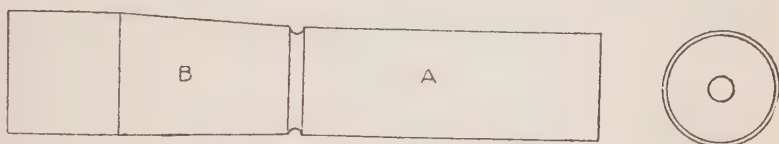


FIG. 41—TYPICAL ARBOR FOR LOCATING LONG BUSHINGS

illustration shows, a hole is drilled in the end of the work to accommodate a driver, A, that is carried by a bracket, B, which is fastened to the grinder face plate by two bolts, D. Such an arrangement is simple to construct and it will give good results if it is proportioned heavily enough to rotate the work satisfactorily under a deep cut.

The shape of the piece to be ground can often be utilized to advantage in locating the work. The stud shown in Fig. 33 is made with a flattened head which permits the driver, B, to be used. The driver is fastened to the face plate, C, and a slight clearance should be allowed between the work and the driver.

When grinding square or hexagon-head bolts, such as auto-

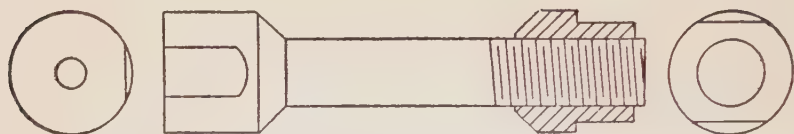


FIG. 42—SPECIAL ARBOR FOR HOLDING TUBULAR WORK

mobile king bolts, the driver illustrated in Fig. 34 can be used. The driver, *A*, is furnished with a hexagon hole slightly larger than the head on the piece. Heavy cuts can be taken while using this driver as no amount of pressure can force the driver and the work apart. The driver is fastened directly to the grinder face plate by the stud, *B*, which permits the part, *A*, to *float* and adjust itself to the work.

Sometimes pieces are designed as shown in Fig. 35, with a lever at one end. Such work is located readily for grinding, it being necessary only to bring the lever end against the face-plate pin. The pin must be comparatively short, however, to avoid striking the wheel when grinding close to the shoulder of the work. It is necessary to provide a special center to grind the lever shown in Fig. 36 as this piece is offset.

Sometimes work is ground between female centers, as shown in Fig. 37. The object of this procedure is to take advantage of the shape of the work, or to finish pieces by grinding that require square ends without center marks. In Fig. 37, the work is driven by a square live center. After the outside diameter is ground, the ends are finished flat in another operation. Where it is necessary to grind pieces with no center marks, however, the work can be handled to advantage on a centerless grinder.

Special centers, as shown in Fig. 38, are used for grinding tubing. The centers are made with a 60-degree angle, the tub-

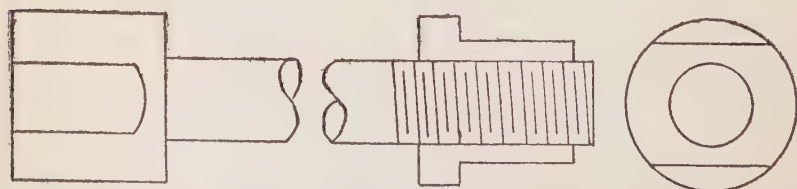


FIG. 43—WORK ARBOR FOR HOLDING A NUMBER OF PARTS

ing being centered slightly at each end. When it is necessary to grind the tubing for its entire length at one setting, a pin is located in the center, as shown at A. This pin fits in a slot milled at the end of the work.

Bushings, rolls and other similar pieces are located on arbors for grinding. A handy grinding arbor for finishing

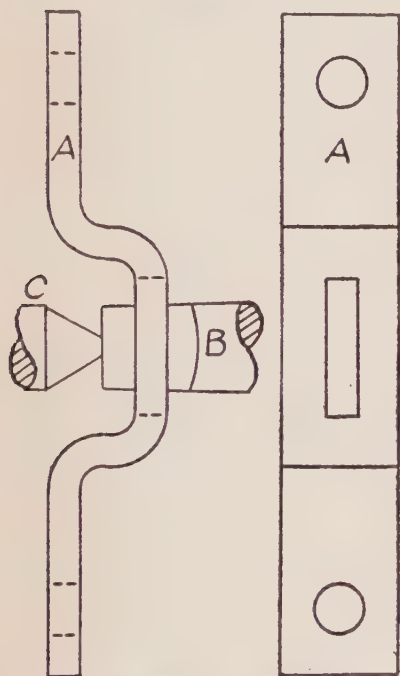


FIG. 44—LOCATING A TWIST DRILL BY ITS SHANK

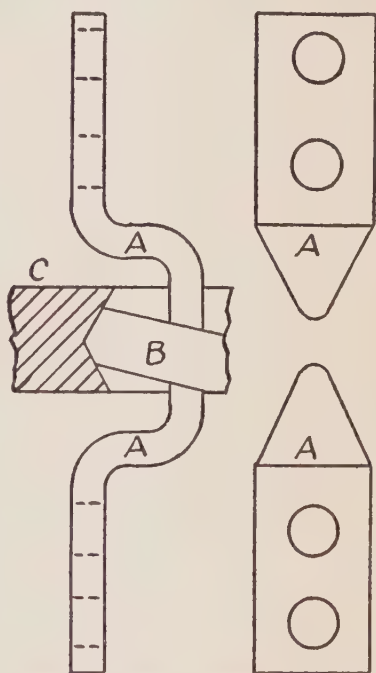


FIG. 45—HOW A TWIST DRILL BODY IS LOCATED

ordinary cam rolls is shown in Fig. 39. This arbor is provided with a driver to engage the face-plate pin so that a dog is not necessary. Sometimes difficulty is experienced in keeping the hole and the outer ground portion of the work concentric. An ordinary arbor is tapered so that it can be forced into the work. If the taper is too abrupt or if the hole is comparatively long, the setting may be faulty as shown in Fig. 40. This illustration is exaggerated to show the principle. The arbor bears in the work at one end only so that the true relation between the hole and the outer diameter of the work cannot be maintained.

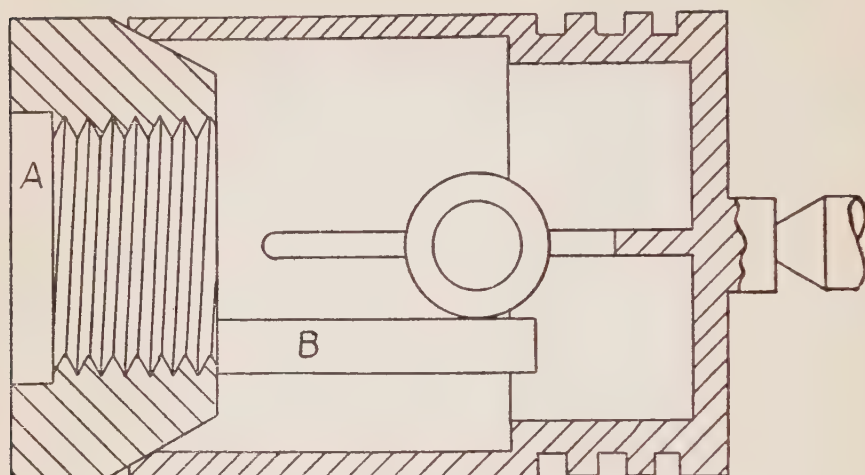


FIG. 46—SPECIAL DEVICE FOR ROTATING PISTONS

Under grinding pressure, the location at the small end of the arbor would change constantly, making accurate results impossible. In grinding work on arbors, it is a good plan to try the work, end for end, leaving it in the position that permits it to pass over the arbor for the greatest distance. Thus, if the hole in the work is tapered slightly (which often is the case) the two tapers make an approximate fit.

A practical arbor for comparatively long work is illustrated

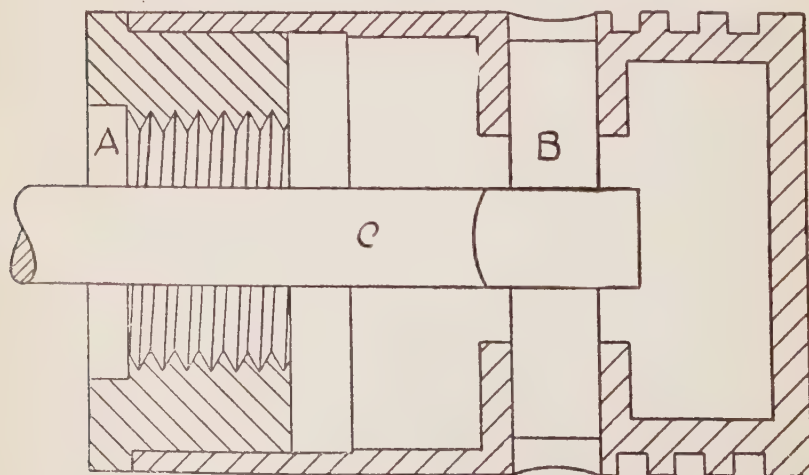


FIG. 47—QUICK-ACTING PISTON LOCATING FIXTURE

in Fig. 41. This arbor is straight at *A* for locating the work accurately, while a tapered portion, *B*, is provided for gripping the work. The straight part acts as a pilot to keep the hole and the outer diameter of the work concentric. It is obvious that the pilot should fit the hole in the work closely. Otherwise, the device is of little value as far as accurate results are concerned. Thus, in grinding work where liberal allowances have been permitted for the bore diameter, three or four arbors, vary-

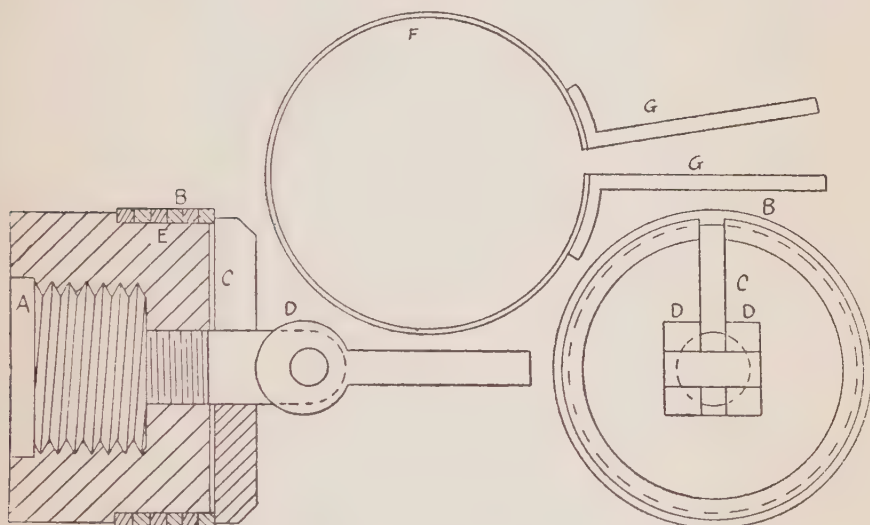


FIG. 48—FIXTURE FOR LOCATING PISTON RINGS FOR GRINDING

ing slightly in diameter, should be provided to take care of the various sizes that come within the plus and minus limits.

The special arbor shown in Fig. 42 is used for finishing tubular parts such as automobile engine piston pins. This arbor is equipped with a tapered shoulder at one end and a nut at the other end for holding the work in place. The pieces to be ground must be countersunk at an angle of 45 degrees to conform to the angular portions of the arbor. When the nut is set up, the work is held in place securely. Such an arbor can be equipped with a driving pin to dispense with the ordinary driving dog.

Cam rolls and similar parts often can be handled to advantage in the grinding operation by locating a number of them

simultaneously on a work arbor as shown in Fig. 43. It is furnished with a collar at one end, made integral with the body, and a nut at the other end which is flattened to accommodate a wrench. When the nut is set up, the parts are held securely as one unit. In finishing rolls by this method the first operation should be to surface-grind the sides. Next, the rolls are located for internal grinding, the outside being finished last.

Judging by its form, it would seem that an ordinary twist drill would present difficult grinding problems. However, this is not the case. The tang end of an ordinary taper-shank drill can be located in the simple driver shown in Fig. 44, which is bolted to the grinder face plate. In this illustration, *A* is the driver, *B* the drill tang and *C* the headstock center. The other end of the drill locates in a female center in the tailstock. In grinding the tang, the drill end is located between two drivers as shown in Fig. 45. In this illustration, *AA* are the drivers, *B* the drill end and *C* the female center necessary for locating the drill end. The two foregoing devices are simple to design and construct and excellent results can be obtained from their use.

Special driving devices generally are employed for locating automobile engine pistons for grinding. In Fig. 46, the inside of the piston skirt is tapered slightly so that it fits over the driver, *A*, which is screwed onto the headstock spindle nose. The piston is rotated by the driver, *B*, which is positioned to bear against one of the piston-pin bosses. The piston is held against the fixture by the tailstock center.

Another piston grinding fixture is shown in Fig. 47. The driver, *A*, is screwed to the spindle nose, while the piston is held in place against the driver by the rod, *B*, which passes through the piston-pin holes and a hole in the drawn-in rod, *C*. This rod passes through the headstock spindle and it is set-up with a hand wheel. For location on this fixture, it is necessary to finish the inside of the piston skirt so that it will fit in place readily. This fixture possesses the advantage of dispensing with the use of the tailstock center.

Great care should be exercised in grinding the outside diameter of piston rings as they must present a true circle when assembled in the cylinder. If they do not fit properly, they will not be gastight which will result in poor compression. Before

the outside diameter is finished, the sides should be ground on a rotary chuck grinder so that they are parallel. For grinding the outside diameter of several rings simultaneously, the fixture shown in Fig. 48 will give good results. The body, *A*, screws onto the headstock spindle nose, the six rings, *B*, being held in place by a split clamp or U-washer, *C*. This washer is held in place by a quick-acting clamp, *D*. The rings are held in the correct location by the boss, *E*, on the body, *A*. When eccentric

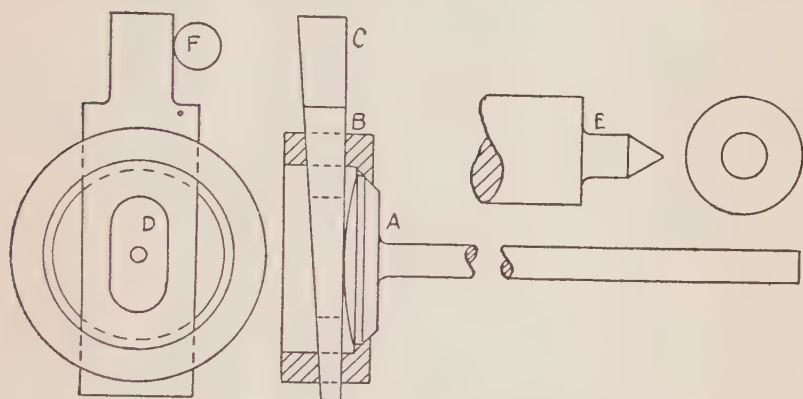


FIG. 49—DRIVER FOR GRINDING AUTOMOBILE VALVES

rings are required, this boss must be eccentric with the body. For concentric rings, however, the boss and the fixture body are concentric. The piston rings are ground on the outside while sprung together. Thus, when in use, they hug the cylinder wall and prevent the escape of gas. To locate the rings in place on the fixture, the device shown at *F* is used. This is a spring-steel clamp, wide enough to accommodate six rings and it is provided with two handles, *G*. When the handles are compressed over the rings after they are in place on the fixture, they can be held in this position while the clamp, *D*, is set-up. In use, this fixture gives good results as far as production time is concerned as the time necessary to unload and load it and to start and stop the grinder should not exceed 15 seconds.

Auto engine poppet valves can be ground rapidly if proper fixtures are provided for holding them. The first operation generally consists of finishing the stem and Fig. 49 illustrates a quick acting fixture for this purpose. The valve, *A*, locates in the holder, *B*, which is slotted to accommodate the wedge, *C*.

This wedge is provided with a slot, *D*, through which the special Center *E*, passes. The work, therefore, can be located readily between the grinding machine centers. It will be noted that the wedge, *C*, is made long enough to bear against the face-plate driving pin, *F*.

The fixtures shown in the following illustrations were de-

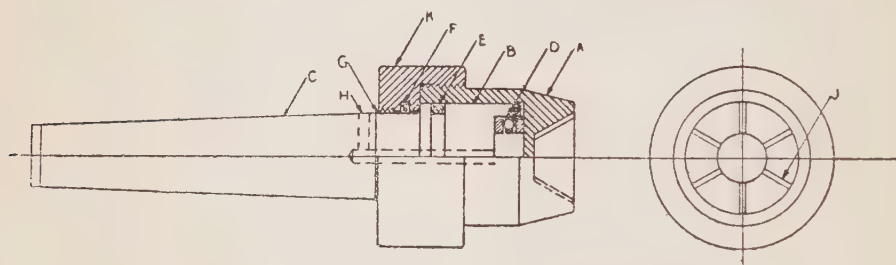


FIG. 50—SPECIAL FIXTURE FOR DRIVING WORK

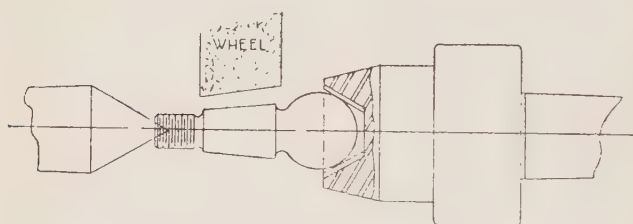


FIG. 51—LOCATING A BALL STUD FOR GRINDING

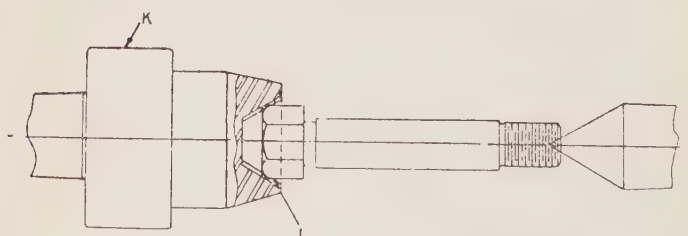


FIG. 52—HOW A HEXAGON-HEAD BOLT IS LOCATED

signed by Roy E. Bender. The device shown in Fig. 50 is for grinding steering balls, king bolts, etc. The device eliminates the center hole usually required. It also can be used in the grinding machine tailstock for locating the ball end of the piece shown in position in Fig. 51. In this case the dog is placed over the threaded part. When grinding king bolts, etc., as

CYLINDRICAL GRINDING

shown in Fig. 52, the hexagon head on the piece locates in six grooves, *J*, while the center is dogged on the outside diameter at *K*. In the upper illustration, the bell mouth, *A*, is provided with a long bearing, *B*, on the body, *C*. A thrust bearing also is provided at *D*. Felt washers, *E* and *F*, exclude dust, while the left-hand thread, *G*, prevents grit from working into the bearing. Hole, *H*, is for lubrication. Its outer end is closed with a small screw tapped into place. The bell mouth part, *A*, and the body,

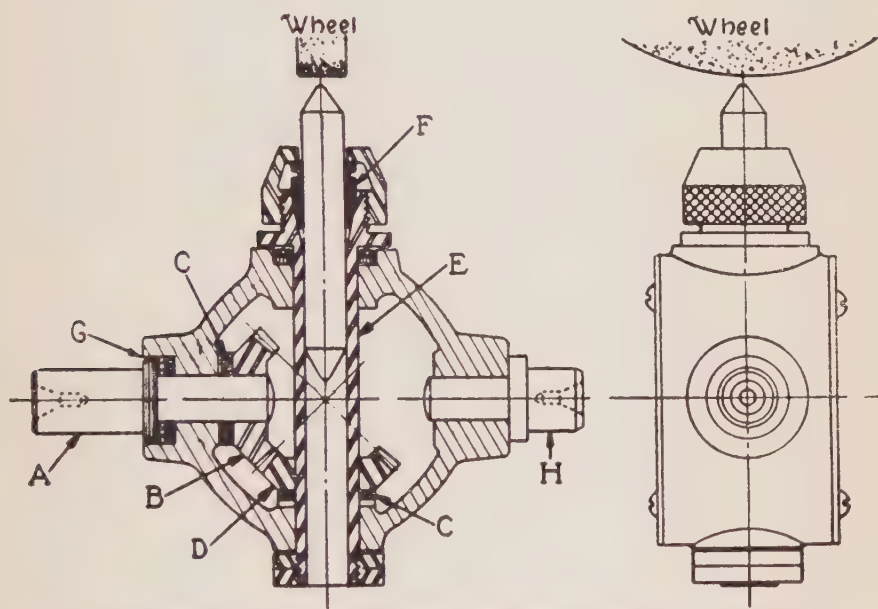


FIG. 53—DETAILS OF FIXTURE FOR LOCATING WORK FOR SPHERICAL END GRINDING

B, are machinery steel case hardened and ground accurately to size.

The pin-gage grinding fixture shown in Fig. 53 produces spherical and conical points at one setting of the work, while the pieces can be ground readily to close limits, leaving from 0.0001- to 0.0003-inch for atoning of lapping to actual size. The fixture is placed between the grinding machine centers, the shaft, *A*, being dogged in the usual way so that power is transmitted from the grinder headstock through the miter gears, *B* and *D*, to the hollow spindle, *E*. The gears are located by set screws, *C*. The shaft, *E*, is fitted with a spring, *F*, which operates in a

taper seat so that when it is screwed down the work is held firmly. Collets of several sizes can be provided.

With the work rotating, the operator grasps the fixture and feeds the work and wheel together until a slight grinding contact is made. It is advisable to use a fine traverse feed in this operation to avoid wearing a groove in the wheel face. By giving the fixture a rocking motion a true spherical surface is generated. Both shafts are equipped with ball thrust bearings to reduce friction, while the left-hand thread, *G*, on the shaft, *A*, just ahead of the thrust bearing, acts as a wiper to prevent grit from working into the fixture. The fixture body is cast iron while the shafts, *A*, *H* and *E*, are steel, case-hardened and finished by grinding. The collet, *F*, also is hardened and ground. As the end view shows, the appliance is equipped with a sheet metal cap on each side to exclude dust.

WORK SPEED

Of all the factors influencing rapid production in cylindrical grinding, the work speed is the most important. A fast work speed means a fast traverse which of course expedited production. Let it be assured for an example that a wheel in an alumina abrasive is used for rough grinding soft-steel shafts, 18 inches long and 2 inches in diameter, removing 0.2-inch of material. The first step is to see that the work is backrested properly. Such a piece should be supported by at least one backrest, while two might give better results. Let it be assumed further that the wheel is 24 combination grit and medium grade. The first question the average operator would ask is how fast should the wheel be operated. That depends on its size to some extent and on other conditions such as the work speed and depth of cut to a greater extent.

Assume that the wheel is 18 inches in diameter and 2 inches wide. Its spindle speed will, of course, determine its peripheral velocity and this can be anywhere from 5000 to 7000 feet per minute. It is safe to begin the investigation by operating the wheel at a normal peripheral travel of 5500 feet per minute. Then set the traverse feed so that the work advances approximately $1\frac{7}{8}$ inches for each of its revolutions. Thus the work will pass the wheel face in a spiral, the ends of which just overlap. In beginning the test, feed the wheel

into the work as much as it will stand. The pulling power of the belt determines the depth of cut. It now is time to watch the results. Suppose the test was started with a normal work speed of approximately 20 feet per minute. Increase the work speed gradually because as the work speed is increased the traverse advances also.

Perhaps the high work speed will cause the wheel to wear away too rapidly, and to the extent of not holding its shape. The most natural thing to do is to reduce the work speed. Also this is the most illogical procedure, for with the work speed reduction, production is lowered. Instead of reducing the work speed, increase the wheel speed. This will make the wheel act harder and cause it to hold its shape. The condition to strive for is to use as fast a work speed and as deep a cut as possible, regulating the wheel speed to conform with these factors. The work speed and the traverse feed should be increased until a safe reversal limit for the feed mechanism is reached. If a new wheel appears soft at a surface speed of 6500 feet per minute it is better to substitute a harder grade than to increase the spindle speed. Wheel speed, depth, of cut, and traverse feed all must be considered together, but the work speed should be set as high as possible and other conditions made to conform to it. A wheel that necessitates a low work speed is not economical as it slows production. The fact must not be overlooked that deep cuts and heavy feeds require hard wheels or high peripheral speeds. For example, wheels now are used successfully a full four grades harder than formerly was thought possible for roughing-out such parts as camshafts and crankshaft bearings. The same rule applies to ordinary cylindrical grinding to a great extent, as the foregoing reveals.

Where the amount of work passing through the grinding room warrants it, the best plan is to divide the grinding operations into roughing and finishing, performing each one on a different machine, or at least with a different wheel. Where one wheel is used for both roughing and finishing, production speed sometimes must be sacrificed to obtain the desired finish.

The fact also must be borne in mind that the diameter of the work influences grinding conditions. For example, the conditions that may prove satisfactory in roughing-out work 2 inches in diameter may not prove economical if the work diam-

eter were increased to 4 inches. This is because the greater diameter of the work increases the arc of grinding contact which will make the wheel act hard. The remedy is to reduce the wheel speed.

Rough grinding of work without table traversing generally is productive of economical results. In this case the work is fed directly to the wheel without traversing until the diameter has been reduced to within 0.002-inch of the finish size. The work is then moved along almost the width of the wheel and another cut is taken, and so on until the entire piece is rough ground. The system is effective, but it involves work on the operator's part so that some grinders are not enthusiastic over the method. Its merits, however, are worthy of investigation.

The manner in which the wheel is dressed has much to do with the economy of a rough grinding operation. Its surface should be sharp and open. The desired surface can be generated with a diamond tool fed across the wheel face with a fairly rapid motion or with a mechanical dresser designed for this purpose. A dull wheel will not take heavy cuts under any conditions.

In considering the rough grinding of cylindrical work the following factors should be kept in mind:

1—The work speed must be as fast as possible, as it is the most important factor affecting the output.

2—The traverse feed must be nearly as wide as the wheel face for each revolution of the work.

3—If a wheel glazes, attempt to overcome the difficulty by increasing the work speed instead of reducing the wheel speed.

4—If the work speed and traverse speed are as fast as consistent with reasonable limits and the wheel glazes, reduce its speed.

5—If the wheel wears out too fast, that is, if it does not hold its shape, do not reduce the work speed—increase the wheel speed instead.

6—Proceed on the principle that a high work speed must be maintained under all conditions and regulate other factors if possible to conform to this.

7—If the design of the machine will not withstand a fast work traverse in roughing, resort to feeding the wheel directly to the work instead of reducing the work speed and traverse.

CYLINDRICAL GRINDING

In ordinary cylindrical grinding practice, the grinding wheel and the work are rotated in the same direction so that the work speed is *positive*. If, however, the work be rotated in the opposite direction a so-called *negative* work speed results. For many years it was thought that a negative speed was not productive of economical results, although it was occasionally used, especially in the operation of tool-post grinders. Many "old timers" maintain that a negative work speed reduces the tendency of the work to chatter, but this theory is open to exception. Centerless grinding machines all employ the negative work speed principle and now that these machines have passed the experimental stage the theory that the negative work speed is not productive of economical results has been disproved. However, with a center-type machine, except in specific cases, it is better to employ the positive work speed.

The following data give work speeds for cylindrical grinding expressed in feet per minute:

Surface Speed of Work in Feet Per Minute

Diam. of work, inches	5	10	15	20	25	30	35	40	45
	Work speeds in revolutions per minute								
$\frac{1}{4}$	76.4	152.8	229.0	305.0	382.0	458.0	535.0	611.0	688.0
$\frac{3}{8}$	50.9	101.8	153.0	204.0	255.0	306.0	357.0	408.0	458.0
$\frac{1}{2}$	38.2	76.4	114.0	153.0	191.0	229.0	268.0	306.0	344.0
$\frac{5}{8}$	30.6	61.2	92.0	122.0	153.0	184.0	214.0	245.0	276.0
$\frac{3}{4}$	25.4	50.8	76.5	101.0	127.0	153.0	178.0	203.0	229.0
$\frac{7}{8}$	21.9	43.8	65.5	87.5	109.0	131.0	153.0	175.0	196.0
1	19.1	38.2	57.5	76.5	95.5	115.0	134.0	153.0	172.0
$1\frac{1}{8}$	17.0	34.0	51.0	68.0	85.0	102.0	119.0	136.0	153.0
$1\frac{1}{4}$	15.3	30.6	45.9	61.5	76.3	91.8	107.0	123.0	139.0
$1\frac{1}{2}$	12.7	25.4	38.1	51.0	63.7	76.3	89.2	102.0	115.0
$1\frac{3}{4}$	10.9	21.8	32.7	43.6	54.5	65.5	76.4	87.3	98.2
2	9.5	19.1	28.6	38.2	49.8	57.3	66.9	76.4	86.0
$2\frac{1}{4}$	8.5	17.0	25.5	34.0	42.2	51.0	59.4	68.0	76.2
$2\frac{1}{2}$	7.6	15.3	22.9	30.6	38.2	45.8	53.5	61.2	68.8
$2\frac{3}{4}$	6.9	13.9	20.8	27.8	37.4	41.7	48.6	55.6	62.5
3	6.3	12.7	19.1	25.5	31.8	38.2	44.6	51.0	57.3
$3\frac{1}{2}$	5.4	10.9	16.3	21.8	27.3	32.7	38.2	43.6	49.1
4	4.8	9.5	14.3	19.1	23.9	28.7	33.4	38.2	43.0
$4\frac{1}{2}$	4.2	8.5	12.7	17.0	21.2	25.4	29.6	34.0	38.2
5	3.8	7.6	11.4	15.8	19.1	22.9	26.7	30.6	34.4
$5\frac{1}{2}$	3.4	6.9	10.4	13.9	17.4	20.8	24.3	27.8	31.3
6	3.2	6.3	9.5	12.7	15.9	19.1	22.3	25.5	28.7
7	2.7	5.4	8.2	10.9	13.6	16.4	19.1	21.8	24.6
8	2.4	4.8	7.6	9.5	11.9	14.3	16.7	19.1	21.1
10	.9	3.8	5.7	7.6	9.5	11.4	13.5	15.3	17.2
12	1.6	3.2	4.7	6.3	7.9	9.5	11.1	12.7	14.3

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Diam. of work, inches	Surface Speed of Work in Feet Per Minute								
	50	55	60	65	70	75	80	90	100
	Work speeds in revolutions per minute								
$\frac{1}{4}$	764.0	851.0	917.0	994.0	1070.0	1147.0	1222.0	1376.0	1528.0
$\frac{3}{8}$	509.0	560.0	611.0	662.0	713.0	764.0	815.0	916.0	1018.0
$\frac{1}{2}$	382.0	420.0	459.0	497.0	535.0	573.0	611.0	688.0	764.0
$\frac{5}{8}$	306.0	337.0	367.0	398.0	428.0	459.0	489.0	552.0	612.0
$\frac{3}{4}$	254.0	279.0	306.0	330.0	357.0	381.0	408.0	458.0	508.0
$\frac{7}{8}$	219.0	241.0	262.0	285.0	306.0	329.0	349.0	392.0	438.0
1	191.0	210.0	229.0	258.0	269.0	287.0	306.0	344.0	382.0
$1\frac{1}{8}$	170.0	187.0	204.0	221.0	238.0	255.0	272.0	306.0	340.0
$1\frac{1}{4}$	153.0	168.0	183.0	199.0	214.0	230.0	245.0	274.0	306.0
$1\frac{1}{2}$	127.0	140.0	153.0	165.0	178.0	191.0	204.0	230.0	254.0
$1\frac{3}{4}$	109.0	120.0	131.0	142.0	153.0	164.0	175.0	196.0	218.0
2	95.5	105.0	115.0	124.0	134.0	143.0	153.0	172.0	191.0
$2\frac{1}{4}$	85.5	93.5	102.0	111.0	119.0	128.0	136.0	153.0	170.0
$2\frac{1}{2}$	76.3	84.2	91.7	99.5	107.0	114.0	122.0	138.0	153.0
$2\frac{3}{4}$	69.5	76.5	83.4	90.4	97.2	104.0	111.0	125.0	139.0
3	63.7	69.9	76.4	82.6	89.1	95.3	102.0	114.0	127.0
$3\frac{1}{2}$	54.5	60.0	65.5	70.8	76.4	81.8	89.4	98.1	109.0
4	47.8	52.6	57.3	62.1	66.9	71.7	76.4	86.0	95.6
$4\frac{1}{2}$	42.4	46.6	51.0	55.1	59.4	63.6	67.9	76.3	84.8
5	38.2	42.0	45.9	49.7	53.5	57.3	61.1	68.8	76.4
$5\frac{1}{2}$	34.4	38.2	41.7	45.1	48.6	52.0	55.6	62.5	69.4
6	31.8	35.0	38.2	41.3	44.6	47.7	51.0	57.2	63.6
7	27.3	30.0	32.7	35.5	38.2	41.0	43.7	49.1	54.6
8	23.9	26.3	28.7	31.0	33.4	35.9	38.2	43.0	47.8
10	19.1	21.0	22.9	24.8	26.7	28.6	30.5	34.4	38.2
12	15.9	17.5	19.1	20.6	22.3	23.8	25.5	28.6	31.8

SECTION V

DIAMOND DATA

Industrial diamonds, which comprise bort, carbon and ballas stones, are used for a number of industrial purposes such as grinding wheel truing, wire drawing, rock drilling, glass cutting, etc. The data in this section are arranged as follows, while additional diamond information will be found in Section I, Abrasive Materials:

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DIAMOND DATA

BORT DIAMOND SHAPES

Bort diamonds are of different natural shapes, and present points and edges, varying in sharpness and number. Certain of them are roundish (rounds) others flat (flats). The different purposes for which bort diamonds are used call for various shapes. Thus for truing wheels, according to Anton Smit & Co., well shaped stones with many points are sought, while for rock-drilling, roundish and blocky shapes are preferred. For diamond dies rather flat stones are used, and for glass cutting 6-point stones, etc. Diamonds are found in a great variety of colors, from pure white to black. The white and grey stones are harder than the brown but more brittle. Users have individual preferences in the matter of color, depending on the nature of the work and the experience of the operators.

CRUSHING BORT

The term crushing bort is used to designate pieces of diamonds, incompletely crystallized, broken, opaque or cloudy, and all fragments unsuited for decorative or industrial purposes. The bort is pulverized and used as a cutting and polishing medium for brilliants and other precious stones, also as a drilling medium in the manufacture of diamond dies, and as a sawing medium for porcelain, etc.

Round crushing bort is preferred, and of this, the Brazilian is most desirable. Its superior quality is due to each single, minute crystal being provided with a tough sheath or skin, which makes it stand up better to the work. Polishers generally buy their own bort and pulverize it in a mortar, as ordinary commercial diamond dust is, as a rule, greatly adulterated with cement, and as a result, it is of poor quality.

DIAMOND CUTTING

Previously to the year 1476, gem diamonds were not cut as they are today; they were used just as they were found in nature. The process of cutting and polishing diamonds was invented in 1476 by L. von Berquen and it has been in use ex-

tensively until the present day. At one time the diamond cutting industry centered in Holland. At the present time, however, large quantities of diamonds are cut in New York City, the industry being contained within the compass of four city blocks in the heart of the business center.

The rough stones come principally from South Africa, where 90 per cent of the world's supply of diamonds originate. These stones usually are octahedral in shape and the first step preliminary to cutting, according to B. K. Price, consists of sawing or cleaving them into workable shapes. In cleaving a stone the expert notes its shape and characteristics carefully. He applies an instrument like a chisel to the desired point of contact and strikes it a sharp blow with a hammer. Great skill is required in this operation since the diamond is very expensive and a slight miscalculation would result in a serious loss. Today, however, the diamond saw is replacing the cleaving process to some extent at least. Diamonds are sawed with a phosphor-bronze disk from 0.0025 to 0.007-inch thick and about four inches in diameter. They operate at approximately 3000 revolutions per minute. It takes about a day to saw a one carat stone. The rim of the saw is impregnated with a mixture of diamond dust and olive oil which forms the cutting agency.

Diamonds are cut by wearing them to a round shape. One stone is revolved at a speed of 1000 revolutions per minute, being held in a special holder, and mounted in a brass *dop*. Another stone mounted in another *dop* is manipulated against the revolving stone by a hand lever which is moved by the operator so that the wear on each stone is about equal.

The next operation consists of generating the desired number of facets on the stone to cause it to reflect the light properly, 58 being the generally accepted number. In some instances, however, special cuttings are employed for various purposes. This operation is performed by holding the stone against a special cast iron disk. These disks are imported from Holland. The diamond is held at the necessary angle by mechanical means while the disk rotates at an approximate speed of 2300 revolutions per minute. Diamond dust and olive oil also is used on this disk to form the abrasive agency.

Three forms of holders are used for locating the diamond. They are called the solder dop, the mechanical dop and the semi-automatic tool. The solder dop has a bronze base on which a mound of solder is fastened. The stone is imbedded by hand in as nearly the desired position as possible. The dop is fastened to an annealed copper rod and by bending this rod, the operator obtains the correct grinding contact. In using this form of dop it is necessary to reset the stone many times during the operation. The mechanical dop incorporates a cup for holding the stone and in some respects it is an improvement over the solder dop. It cannot be used, however, for cutting the *table* or top of the stone.

The semiautomatic tool is equipped with refinements for locating the stone accurately to generate the facets. The stone does not have to be removed from its setting during the faceting operation and in consequence the facet angles all are alike. In the operation of this tool it is necessary to reset the stone twice only. The diamond is set in an aluminum dop that is cast around it.

DIAMOND DIES

Diamond dies for drawing wire are of great value to the electrical and other industries where importance is attached to accurate and uniform cross section. Great quantities of wire can be drawn through these dies without variation of diameter. For this industry, rather flattish stones are used, and hardness at the center where the wear takes place is essential. Quality is a most important matter which accounts for the great variation in the prices of dies. The diamonds are pierced on precision machines by means of fine steel needles charged with diamond dust and oil. The manufacture of the smallest sizes having diameters of 0.0004-inch and less, calls for great care and years of experience. After piercing, the diamonds are set in brass or steel mounts.

DIAMOND POINTS

These, as their name implies, are elongated thin stones, and may be obtained in the natural state, cleaved, sawn or polished. They are used for drilling glass, for graduating measuring and astronomical instruments, and for graving tools of different kinds.

DIAMOND DATA

DIAMOND POWDER

A substance formed by crushing diamonds and grading the resultant powder in olive oil. The process consists of crushing imperfect stones in a small steel mortar. This mixture is placed in a quantity of olive oil and stirred thoroughly. It is permitted to stand for five minutes. The oil then is poured off and the material remaining in the receptacle is called No. 0. The oil then is permitted to stand for ten minutes and after pouring off what remains in the bottom is called No. 1. Thirty minutes yields No. 2; one hour, No. 3; two hours, No. 4; and ten hours, No. 5. Letting the oil stand until it shows clear yields the finest grade, or No. 6. Diamond powder is used for cutting diamonds and for various mechanical purposes.

DIAMONDS FOR ROCK DRILLING

Formerly, the only means of sinking bore-holes in hard rock was by means of percussion and hammer-drills, according to Anton Smit & Co. The bore-dust accumulated in this way gave a very poor indication of the composition and sequence of the strata. It was only towards the middle of last century that engineers first took advantage of the intense hardness of the diamond for drilling operations.

A boring crown, set with diamonds, and fixed at the end of a system of hollow rods, is brought to bear on the rock with even pressure, and revolved at great speed. In this way a ring-shape hollow space is cut around a stationary, cylindrical core of rock. A stream of water converts the bore-dust into silt, which is brought up to the surface. As the diamond crown bores down, the core is received into a core tube and fetched up from time to time. These cores give a very precise indication of the character, as well as the sequence and dip of the strata, besides affording the most excellent material for analysis.

Carbons, black Brazilian diamonds, are generally used for this class of work. These stones, with ballas are the hardest and toughest of all diamonds. Cape and Brazilian bort are used for drilling ground of medium hardness, and of these the Brazilian, being the hardest, is used in preference. For very hard formations such as volcanic rock, quartz and conglomerate, carbons only are satisfactory, their structure rendering them stronger

and less brittle than borts which easily split on account of their laminated formation. For best results it is advisable to set several ballas in the crown with the carbons.

All diamonds can withstand great pressure, but they are very sensitive to shock or blows. Apart from the quality of the diamonds and their perfectly secure setting in the crown, their life will greatly depend on the experience and care of the operator. Prolonged work on uniform rock of the very hardest, densest character is less harmful to the diamond than boring through strata alternating from hard to soft. In such instances the diamonds, besides being called on to withstand pressure, have to resist the shocks caused in passing from one stratum to another.

The size of diamonds used for boring depends on the diameter of the crown, the most usual sizes being from $\frac{3}{4}$ to 6 carats. The diamonds are spaced at equal distances around the base of the crown, alternately on the inside and outside edges. Each diamond covers slightly more than half the thickness of the wall of the crown. It is a common practice to set two or four diamonds half way up, around the inside and outside faces of the crown. Those on the outside serve to give a little more play for the crown and to reduce the wear of this part; those on the inside enable the core to pass freely.

It is generally recognized as the best practice to use diamonds of the largest size the crown can carry. The larger the stone the better it resists hard usage, and it is therefore the more economical in the long run. Moreover, large stones are more easily and securely set than small ones, and the risk of losing them while in use is less.

Diamond core drills are used for driving bore-holes to all depths from 15 to several thousand feet. They are made in a large range of diameters from 36 millimeters for ore prospecting up to 50 centimeters for borings in coal mines and for oil wells.

The diamond drill is also of great value in locating suitable foundations for bridges and other large structures, which must rest on bedrock. It further finds an important use in mines for making emergency borings, where a sudden inrush of water or gas is expected, and for rapidly establishing ventilation. It has also proved of inestimable service in the extinction of under-

DIAMOND DATA

ground fires in mines. A comparatively modern use for the diamond drill is the cutting of cores from cement roads to ascertain if the cement was laid according to specifications.

DIAMOND SAWS

These are made in various patterns, including circular saws up to 10 feet in diameter, reciprocating saws up to 25 feet long, hand saws and slitting saws. The cutting diamonds are mounted in detachable steel sockets inserted at regular intervals along the saw.

DIAMOND SELECTION

The selection of diamonds for wheel truing is a difficult matter for one who does not understand the subject thoroughly. For this reason it is a good plan to buy diamonds only from dealers of recognized standing who have a reputation to maintain. Of the two general varieties of stones, bort and carbon (carbonado) both will give good results. Carbon stones are comparatively high in price, but they are extremely durable as they present no cleavage lines.

Black, brown and gray bort stones are said to be quite hard, but they will shatter if they are not correctly set. These stones are found generally in the shape of octahedrons and many grinding room foremen favor this shape as it lends itself readily to setting and resetting. Again, many authorities favor the round or *bull-nose* stones. The so-called *ballas* stones make excellent wheel truing mediums as they have no cleavage lines. These stones are comparatively expensive, but they are quite tough. Brazilian stones are hard, but brittle. Thus they cannot be entrusted to an inexperienced operator. They are said to be excellent to use in hand wheel-truing tools. The following data compiled by Anton Smit & Co. will be useful in selecting diamonds for truing wheels of various sizes:

Diameter.	Face.	Size of Diamonds.
up to 6 inches	1 inch	$\frac{3}{4}$ carat.
6 to 12 inches	1 inch	1 to $1\frac{1}{4}$ carat.
12 to 18 inches	1 to $1\frac{1}{2}$ inches	$1\frac{1}{4}$ to 2 carat.
18 to 24 inches	2 to 4 inches	2 to 5 carat.
For Hard Wheels:		
Diameter.	Face.	Size of Diamonds.
up to 12 inches	1 inch	$1\frac{1}{2}$ to 2 carat.
12 to 18 inches	1 to $1\frac{1}{2}$ inches	2 to 4 carat.
18 to 24 inches	2 to 4 inches	4 to 10 carat.

Large stones possess one distinct advantage in that they can be reset a number of times while small stones, of course, can be purchased more economically.

DIAMOND SETTING

The setting of industrial diamonds is an operation that should be entrusted only to an expert, for a novice can ruin a good diamond by setting it improperly. The various methods followed in setting diamonds are the mechanical, peining, brazing and casting.

Mechanical setting consists of the use of special chucks for holding the stone by clamping means. Many ingenious devices have been developed, but it is doubtful if they possess superior merits under all conditions. In peining a diamond in place the operation is as follows:

First a copper nib is drilled as shown in the accompanying illustration at the left. The hole is drilled just deep enough to



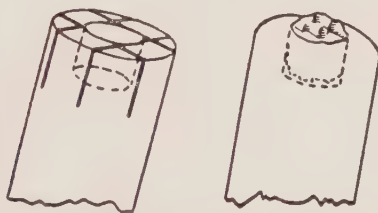
PROGRESSIVE STEPS IN SETTING A DIAMOND BY THE PEINING PROCESS

bury the stone. Next, as shown in the center illustration, the metal is peined over by hammer blows, generally through the use of a staking tool, to hold the stone firmly in place. This is an exacting operation for a chance blow will fracture the stone. Last, as shown at the right, the metal at the top of the nib is turned away to expose the stone slightly. This method possesses the advantage of being easily carried out and, no doubt, it will hold comparatively small stones successfully. Its disadvantages are that the stone is not always held securely and, as stated above, a false blow during the peining operation may fracture the stone.

In brazing a diamond in place the nib is drilled to accommodate the stone. Then the hole is filled with spelter which is

brought up to the melting point, usually by a blow-torch flame. Then the stone is inserted in the molten metal and pressed securely in place, the heat being kept up the meanwhile so that the stone will not cool the spelter too rapidly. This method is said to be satisfactory, but it is thought by many diamond experts to expose the stone more or less to combustion, which begins to take place when air or oxygen has free access to the diamond surface at a temperature of 1562 to 1832 degrees Fahr. Again the brazing method is liable to leave gas pockets around the stone. Further the stone is simply surrounded by a matrix of rather weak material, that is brass.

J. M. Henry supplied the following data pertaining to the method followed in mounting diamonds in place by the brazing method at the works of the Pratt & Whitney Co. The shank, as shown in the accompanying illustration at the left, is a soft-



THE VIEW AT THE LEFT SHOWS
A SHANK READY FOR DIAMOND
MOUNTING WHILE THE ILLUS-
TRATION AT THE RIGHT IS THE
FINISHED SETTING

steel bar and the first step in preparing the setting is to drill a hole approximately as large as the greatest diameter of the stone when it is in the position judged to be the most satisfactory. Next four saw cuts are made. With the stone in place, molten spelter is poured into the slots and the drilled hole, which sets the stone firmly. The spelter that flows into the slots anchors the setting in a satisfactory manner. The illustration at the right shows the setting ready for use after the shank has been rounded over at the end.

The casting method gives excellent results in the hands of an expert. Howard Miller, head of the testing laboratory of

the General Electric Co., gives the following formula for a casting alloy:

Zinc	90 per cent
Copper	5 per cent
Aluminum	5 per cent

He states that this alloy has a melting point of 650 degrees, Fahr., and a Brinell hardness of 78 and that the relatively low melting point will not injure the stone. This material is called Sampson metal. Mr. Miller's process is to hold the stone by supporting wires in the bottom of a split mold similar to a bullet mold. The mold and stone then are heated slowly to a temperature of 350 degrees Fahr. The mold then is poured full of the molten alloy which previously has been melted in a small electric furnace. Thus the stone is cast solidly in a matrix, or nib, the shape of which is governed by the mold.

Diamonds also are set by casting steel or a steel alloy around them. Prof. Robert E. Lyons states that he found no change in any number of diamonds that had been set by casting steel around them five times.

Frank B. Wade, who has made an exhaustive study of diamonds, states that the casting of a suitable metal or alloy around the diamond is the best of the holding methods that have been devised.

Diamond tools should be inspected frequently and turned in for resetting as soon as the cutting surface has been worn appreciably flat. This work can be performed in the plant of any manufacturing company, provided the necessary facilities and a skillful operator are at hand. In the majority of instances, however, it is considered a better plan to return worn diamonds to an industrial diamond dealer for resetting. The charges for this service are quite normal and the results are satisfactory.

GLAZIERS' DIAMONDS OR VITRIERS

These are very small bort, as many as 80 running to the carat, and are used for cutting glass. These stones are obtainable in a wide range of qualities.

DIAMOND DATA

HINTS ON USING DIAMONDS

The following pertinent hints on the use of industrial diamonds for wheel truing is given by Howard W. Dunbar in his book, *Little Known Facts About Grinding*:

Don't forget that bull-nose diamonds frequently reset give a lower cost for wheel truing.

Don't forget to set the diamond tool below the wheel center—never above it.

Don't quench hot diamonds.

Don't forget to flood diamonds with water or other cooling lubricant while they are in contact with the wheel.

Don't forget to change the position of the tool frequently so that a large surface of the diamond is never in contact with the wheel.

Don't forget to take light cuts.

Don't exceed 0.001 to 0.002-inch depth of cut with the diamond.

Don't run the diamond too slowly across the wheel face if it is desired to break up the surface to make the wheel cut freely.

Don't forget that the smoother the point of the diamond, the smoother will be the finished work.

Don't think of the diamond as a device for sharpening the wheel, but rather as a tool for correcting the surface.

SHAPED DIAMOND TOOLS

Tools containing specially shaped diamonds are in ever increasing demand for turning, threading, truing of various rolls in paper mills, and generally, for accurately and rapidly working hard fibrous substances such as ebonite and vulcanite. The great advantage in using diamond tools for these purposes is that they will produce highly accurate work for long periods without regrinding, whereas the best high speed steel quickly burns and wears down under the same conditions.

SPLINT DIAMONDS

The splints which accumulate when cleaving diamonds are assorted into coarse, middle and fine. Prudence should be ob-

served when purchasing splints, which should only be bought from firms guaranteeing 100 per cent pure diamond. Unscrupulous dealers add foreign matter in proportions up to 40 and 50 per cent, which although relatively hard, costs scarcely anything, and thus explains the cheapness of this substitute. Splints are used mainly by optical and glass works.

SECTION VI

DISK GRINDING

Disk grinding, which in reality is a branch of surface grinding, is not an innovation as it dates from the time when a sheet of emery or other abrasive material was glued to a wood face plate and used as a more speedy finishing or polishing process than could be afforded by the use of hand material. The growth of modern disk grinding has been rapid. According to F. E. Gardner, it dates to the time when some 40 years ago F. H. Gardner and Charles H. Besly developed a small hand-feed machine for finishing small tools. Following is a list of the subjects included in this section:

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Disk Grinding Problems	133	Thick Abrasive Circles.....	138
Selection of Abrasive Disks.....	136	Truing Abrasive Disks.....	140

DISK GRINDING

DISK GRINDING PRACTICE

Disk grinding is an economical procedure as it can be used for finishing flat surfaces that heretofore were placed or milled at considerable expense. In designing parts for finishing by disk grinding, the finish allowance also can be reduced materially which results in a substantial saving of material. At one time disk grinding was considered a rough operation only, but present day disk grinders of many types are precision machines. The nature of the work directs the type of machine to use. For finishing flat surfaces on large parts, the horizontal-type machine carrying a large disk is the most economical. The machine bed is fitted with cross members to prevent the work turning so all that is necessary is to place the pieces on the rotating disk. Comparatively light pieces, however, can be weighted to advantage. As these large machines will accommodate a number of pieces, one machine can be kept practically in continuous operation. The semiautomatic machines of this type which are equipped with fixtures for locating the work and bringing it in the grinding position are productive of excellent results.

Small work generally is ground on vertical disk machines fitted with lever feed tables. Usually it is necessary to provide holding fixtures which are located directly on the table. One disadvantage of this type of equipment is that the piece must be rocked back and forth past the disk face by hand while also the grinding pressure is applied manually. This results in fatigue on the part of the worker which lowers production. However, this objectionable feature has been overcome by the design of disk grinders with automatic feeding and pressure regulating arrangements.

A special type of disk grinder for wood work called a patternmaker's disk grinder shows high efficiency in the pattern shop. Such machines are equipped with numerous adjustments so that it is possible to generate angles readily for the purpose of putting draft on patterns, etc. Again, by the use of these machines, patterns can be made from second-grade lumber as a few knots in the material are not detrimental to good disk grinding practice. The patternmakers' disk grinder is an excellent production machine.

DISK GRINDING

Hand operated double disk grinders are used for finishing a diversity of pieces of metallic and nonmetallic materials. The work is held on a special locating fixture which is passed between the two disks, one being provided with a longitudinal movement. It comes against an adjustable stop which should be regulated to control the thickness of the finished product. The disks should be trued as soon as they cease to cut freely. A special dresser is used for this purpose. Automatic disk grinding machines are used in cases where large quantities of repetition work are handled. Such machines give efficient results. They are used extensively for finishing the sides of piston rings, washers, ends of rods, coil springs, etc.

In designing parts for disk grinding it is well to remember that an abrasive instead of a metal cutting element is to be used, so that a minimum grinding allowance only will be necessary. When parts are to be milled or planed it is necessary to allow a liberal allowance to enable the tool to get under the scale. With disk grinding this is not necessary as the abrasive starts on the hard scale and works in. Parts with broken surfaces are finished more readily than solid sections. This point also is well to bear in mind when redesigning parts for finishing by disk grinding.

A factory producing special fittings for a large steam and plumbing supply jobber, according to Donald A. Hampson, was called upon to produce a quantity of boiler room specialties that included the casting shown in Fig. 1. This unit is the major part on which others are assembled. It is a brass casting about

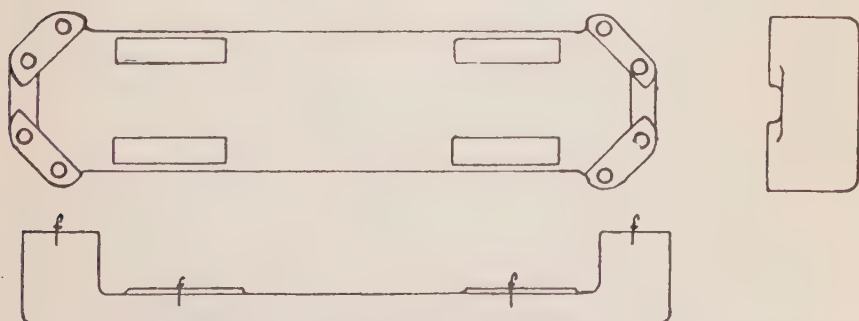


FIG. 1—TWO SURFACES OF THIS PART WERE FINISHED BY SIMULTANEOUS DISK GRINDING

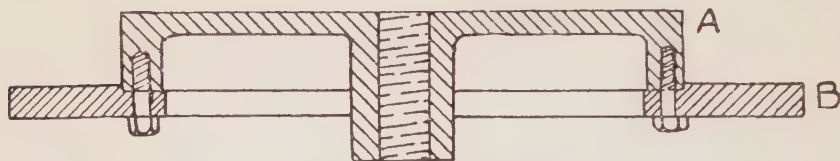


FIG. 2—THE DISK WHEEL IS MADE IN TWO SECTIONS WHICH ARE HELD TOGETHER WITH SCREWS

10 inches long on which a stamped case, gage glass and other parts are attached.

In the design of the part, the present shape is conceded to be far superior to any other that might be made, but it is a shape that does not lend itself readily to speedy manufacture because of the machined surfaces being at two levels. Thus inside cuts are necessary, which are always awkward and slow. The way to design such a part for economical manufacture would have been to have the risers at the ends left off entirely so that the casting could be dressed off at once and in one plane. This however, would require separate pieces for the ends and a joint that might be hard to keep tight.

One of the production men conceived the idea of disk grinding the parts by means of a disk having one surface offset from the usual face, in the manner detailed at Fig. 2. The plan was to machine the parts on a disk grinder that would finish both heights at once and with the desired spacing. To this end, some minor changes in size were made to reduce the area to be ground and the castings then came to the machine shop in the form shown in detail in Fig. 1. A floor grinder was available and on this machine the disk was attached. It was screwed directly on the spindle with a 1-inch diameter, 6-pitch, left-hand thread. This disk was in two parts, the main piece, A, including the hub and a rim being turned all over. To the back of the rim was bolted a plate, B, with four $\frac{3}{8}$ -inch hexagon head cap screws. This made it easy to remove the disk for cleaning and mounting. Being shouldered as shown, it always went back concentrically. An abrasive disk was cemented to each plane face. They produced satisfactory work; the variation due to wear and other causes having been found to be a maximum of 0.004-inch, which was negligible for this job.

Thus an awkward part was turned out at little cost and probably much more accurately than by any cutting tool method.

Being of light section and of brass, such a piece could have been held in a vise of a fixture without distortion. Held free hand against a disk wheel, there was practically no chance of springing the work.

Regular 12-inch carbide of silicon disks were cut in two sections, one to go on each surface of the double disk wheel. Large lots of the pieces were not put through; so there was plenty of time to renew the abrasive. The separable feature of the wheel made it easy to clamp the disks for setting in the press. A novel method is used to make the disks easily removable from the spindle. An ordinary cheap thrust bearing is slipped on, next the spindle flange and with this unit in place a disk is never jammed so that it cannot be removed with the hands.

DISK GRINDING PROBLEMS

A point to consider in disk grinding is the use of jigs and fixtures for locating work. In cases where a quantity of similar parts are being ground it pays to design and install simple holding fixtures for various parts. In this way, the handling time is reduced to a minimum while the time consumed in designing and constructing such fixtures is more than offset by the reduced production cost that ensues. The design of the pieces to be ground is of the utmost importance and it often is possible to redesign a part in such a manner that the production time in disk grinding can be reduced materially. The chief aim should be to present to the abrading circle as small an area as possible. Many parts that formerly were machined on other types of machine tools have been redesigned so that by disk grinding, from 50 to 90 per cent of the production time has been eliminated. The selection of abrasive circles is of equal importance and when in doubt it is a good plan to present the problem directly to the disk or machinemaker.

In selecting work for the disk grinder the following points should be kept in mind: The amount of stock to be removed, the distribution of the ground surface, the total area to be ground and the thickness of the adjacent stock for absorbing the heat generated in grinding and for resisting distortion. By exercising care in the design of the part, production will be expedited materially, which results in a reduced production cost.

The finish allowance on parts to be disk-ground is much less than in cases where the finishing is to be performed by milling or planing, so that designers who are conversant with present-day disk grinding practice generally designate disk grinder finish on their drawings. The patternmaker on seeing such a notation leaves but a small amount for finish on the pattern. In many cases, the molder will often rap a pattern enough to leave sufficient stock for disk grinding in case of an emergency.

The cost of disk grinding usually is directly proportional to the amount of stock removed, which makes a small finish allowance imperative. In some cases the removal of from 0.005 to 0.05-inch is enough to clean up a surface satisfactorily while under other conditions as much as $\frac{1}{4}$ -inch can be removed profitably from iron or brass castings. Generally, however, the finish allowance in actual practice follow:

Drop-forged wrenches, 0.008 to 0.015-inch.

Brass hexagon nuts up to 2 inches in diameter, 0.015-inch.

Brass hexagon nuts in larger sizes, up to 0.03-inch.

Steel punchings, 0.005 to 0.015-inch.

Cast iron machine parts, 0.003 to 0.06-inch.

Cast brass machine parts, 0.015 to 0.09-inch.

These amounts may vary slightly, as much depends on the nature of the material, the speed of the abrasive circle and the distribution of the ground surface.

Cast metal is more readily finished by disk grinding than rolled or wrought material, while soft stock is easier to grind than work that has been hardened. In cases where iron castings are small and of thin section, the material often is hard and difficult to grind. The scale on castings and forgings wears the abrasive disks unduly so that in cases where the scale is excessive, it is a good plan to remove it before grinding. The scale can be removed on a regular grinding wheel, or on a ring wheel held in a ring-wheel chuck mounted on one end of the disk grinder spindle. The scale also can be broken by tumbling, sandblasting or pickling. Where forgings or hot-rolled materials are excessively scaled, they should be pickled.

The speed at which the abrasive disk is operated is an important factor to consider and on soft material, a comparatively high speed is essential. As the abrasive travels at varying velocities from the center to the periphery of the disk, it

would seem that the disk speed was not of great importance. In actual practice, however, it has been proven that the average speed of the abrasive should be given consideration. When in doubt regarding speeds, it is a good plan to consult the disk grinding machine manufacturer, stating all the details of the operation. In this way the benefits of experimental and actual disk-grinding practice are obtained readily, for example, it is generally known that an excessive abrasive speed on hard material has a tendency to glaze and dull the disk, while a low speed when grinding soft metal fills and clogs the circle. Again, an excessive speed on wood and other nonmetallic substances tends to burn the work. While these factors are known generally, the operators in many plants wear out disks quickly because of the lack of attention to details. Disk grinding should be performed dry, for if water is utilized to carry away the abrasive dust, the circles will be destroyed, as the glue that holds the abrasive in place is not waterproof.

In disk-grinding practice, the entire surface to be finished usually is in contact with the disk so that innumerable cutting points are at work simultaneously. As the cutting points pass over the work at high speed, the friction resulting generates heat. For this reason a sharp, free-cutting disk creates less friction than one that is dull or glazed. When the feeding pressure is insufficient, the cutting points of the abrasive rub or brush the work instead of cutting as they should. This also creates excessive friction. Practically all the heat generated in disk grinding is caused by ground particles rolling between the circle and the work. The greater distance these particles are carried over the ground surface before being discharged, the greater the heat generated. Thus the importance of correctly designed surfaces for disk grinding is apparent, for if the surface to be ground is broken so that it does not present an unbroken plane, the grindings are discharged before excessive heating results. The work should not be permitted to overheat unduly as cold metal is easier to grind than heated stock. Also hot metal will destroy the glue that holds the abrasive in place. The expansion from frictional heat seldom is distributed evenly throughout the work and this unequal expansion often warps the part being ground. If grinding is continued while the part is distorted, it is apparent that the ground surface will not be

flat after the work has cooled and contracted. Thus, undue heating should be avoided and the work should not be allowed to become too hot to be handled conveniently by the operator.

To eliminate the generation of heat as much as possible, the abrasive circle should be sharp and free cutting at all times. The coarsest grain that is practicable should be used, while sufficient feeding pressure should be maintained to make the disk cut freely. When the disk becomes glazed, it can be resharpened by passing a dresser over it lightly. A stiff wire brush also can be used to advantage when grinding such materials as carbon, brass, cast iron, etc. The correct feeding pressure varies, but the work never should be forced against the circle for more than from 3 to 20 seconds at a time, the period depending on the nature of the work. If the work gets too hot before sufficient stock has been removed, it is a good plan to handle it a second time when grinding, allowing it to cool between the first and second operations. Generally speaking, however, in cases where the parts are designed properly for disk grinding, overheating does not occur frequently. As previously stated, excessive heating is caused by the grindings traveling between the disk and the work while the principal methods followed in reducing the travel of these ground particles are to recess the work, rotate it during grinding, or to restore to the use of grooved circles.

SELECTION OF ABRASIVE DISKS

No general rule can be cited to follow absolutely for the selection of abrasive disks. In general it can be stated that carbide of silicon gives good results for grinding cast iron and brass and aluminum oxide for steel. Garnet and emery disks also are used extensively. Garnet is ideal for woodworking, while emery is used for disk grinding various nonferrous materials.

The finish desired should govern the grain of the material. As a rule nothing coarser than No. 16 is used for finishing a surface less than three square inches in area. Nothing coarser than 16 is used for finishing steel or brass with the exception of steel castings. Nothing coarser than 24 should be used for finishing hard steel except in extreme cases. Grits coarser than 24 seldom are used on brass unless a large amount of stock is to be removed or where a fine finish is not necessary. No.

46 is used extensively for grinding small surfaces on brass and for the finish grinding of cast iron and steel.

All grain sizes from 12 to 70 are used on cast iron the size being dependent on the amount of stock to remove, the area of the work and the finish wanted. In general, where the surface is more than three or four square inches in area, No. 12 or 16 will be satisfactory. In selecting disks for various purposes it is a good plan to consult the disk maker's representative who is in a position to make intelligent recommendations.

SETTING UP OF DISKS

Abrasive disks cannot be depended upon to give entire satisfaction if they are not cemented in place properly on the disk wheels. The following suggestions for setting up disks were supplied by Charles H. Besly & Co.:

Make sure that the disk is absolutely clean and free from grease, oil, and rust. Wash it with hot lye water and see that the grooves (if spiral groove disks are used) are free from old cement and glue. After the disk wheel is cleaned, thin some disk cement with an equal part of water and use this solution to scrub the disk wheel thoroughly. Then wipe it off with clean waste or a clean cloth. Never use oily waste or gasoline and do not touch the face of the cleaned disk with the hands. This is important. Place the disk wheel on the disk press and coat it heavily with cement. Apply the cement evenly and see that all grooves are filled. Then coat the back of the abrasive disk with cement, brushing it in thoroughly so that the heavy duck backing will not absorb any more. The backing acts as a blotter and if it is not well coated it will absorb the cement from the disk wheel and a good job will not result. Next place the abrasive disk on the disk wheel and lay a felt pad on top of it. If a felt pad is not available use several thicknesses of cloth. The pad acts as a cushion between the face of the disk and the press plate to take up any unevenness which may be present. Clamp the press plates tightly. After the disk has been in place a few moments it will be found possible to give the clamps a few more turns. Let the disk remain in the press at least 24 hours. Then remove it and let it stand in the air for at least 48 hours more before using it.

In damp or humid weather the cement may not dry out

as thoroughly and as rapidly as under more favorable conditions and it may be necessary to permit more time for drying. It is important that the disk be dry before being put in use. After the disk is dry and ready for use trim away any of the cement at the edge with an old file or rasp. Before starting to grind, it is well to dress the disk face using the truing device on the lever feed table. If the machine has a plain table, use an ordinary grinding wheel dresser. Never handle the disks with greasy hands.

THICK ABRASIVE CIRCLES

Thick abrasive circles are a comparatively recent development. In the early days of disk grinding, paper and cloth back disks sufficed, but with the demands for increased production it was found that stronger materials were necessary. The circles in question are from $\frac{1}{4}$ to $\frac{3}{8}$ -inch thick. They can be made in various grades to suit different classes of work. They also are furnished in several bonds. As they can be trued like an ordinary grinding wheel, they afford an efficient grinding medium; a compromise between ordinary disk and a ring wheel. The following data pertaining to setting up thick abrasive circles was furnished by the Gardner Machine Co.:

Care of the wheels to which the disks are fastened is of the utmost importance. New wheels must be cleaned thoroughly with gasoline to remove oil and antirust compound. After the wheels have been in use, cleaning with hot water is sufficient.

Next the wheels should be scrubbed with a solution composed of disk cement and water mixed in equal quantities. Afterward they are wiped dry and placed in a box of sawdust. In no case should the face of the disk wheel be touched with the hands after it is cleaned. If the disk is not clean the cement will not adhere to it.

Special cement should be used to fasten the disks in place. A thin coating should be applied to the back of the abrasive disk with a brush. If the cement is too thick it can be thinned with water. The coating should be light, but should be evenly applied and well rubbed in with the brush. A thin coat of cement is applied to the steel disk. If it does not spread evenly and if it has a tendency to gather in drops, it is an indication that the disk wheel was not clean before the cement was applied.

While the cement is sticky, the disk is placed on the disk

DISK GRINDING

wheel, abrasive side up, and disk and disk wheel are set on the disk wheel press. A circular felt pad, $\frac{1}{4}$ inch thick, is placed over the abrasive side of the disk. Another disk is placed over this which also should be covered with a felt pad. The press top then is placed in position. It is not advisable to place more than two disks in the press at one time.

In applying the pressure, care should be exercised to prevent the disks from slipping from the correct location on the disk wheels. The pressure should be applied evenly by setting up each screw a little at a time. It also is advantageous to use a centering device consisting of a disk about $\frac{1}{8}$ -inch thick of the same diameter as the center hole in the disk. This center should be provided with a hub to fit the hole in the disk wheel. This device insures locating the disk in place correctly.

A special pneumatic diaphragm press is used for setting up large 53-inch disks which are made in four sections. After the steel disk wheel has been cleaned as previously described, the four disk sections are coated with cement. Next, the disk wheel is coated. The disks are set in position and the press is located over them. Felt pads are not necessary with this press. The press is clamped in place and air pressure is applied with a pump. This should be done as quickly as possible so that the cement will not have a chance to dry before the pressure is applied. The pressure gage should register from six to seven pounds. It is advisable to detail two men for this work. The time necessary for drying varies with the condition of the atmosphere. In clear, warm, dry air the disks should be dried six hours in the press and 10 hours more before being put to use. If the air is damp and the humidity is high, the drying time should be increased to between 24 and 48 hours. It is not advisable to try to operate a disk grinding department with a few disk wheels only. A sufficient number of wheels will eliminate the tendency to put the disks into use before they have dried thoroughly.

Where only a moderate amount of disk grinding is performed, it is a good plan to set up the disks near the close of the working day so that they can remain in the press over night. After the set-up disks have dried thoroughly, the edges should be trimmed with an old file. Any superfluous cement on the center of the disk wheel should be scraped off also. This is

important for if the center portion is not clean the disk will not run true on the disk grinder.

With the disk wheel in place on the disk grinder it is a good plan to rub a light piece of metal over it. Sections on the surface that emit a hollow sound indicate portions where the disk is not cemented in place thoroughly. There is no remedy for this and such a disk will wear out first at the loose spots.

Old disks are removed by soaking the disk wheel in hot water. Cold water is not as effective as it increases the removal time. If the disk is not worn down to the cloth backing, soaking in hot water followed by striking the disk with a hammer will remove it readily. Care must be used in handling thick abrasive circles before they are attached to the disk wheels. These disks are brittle so that they fracture easily

If a disk is cracked before attaching it to the disk wheel, it need not be discarded, unless the cracks are numerous or a piece of the material is missing. Such a disk should be attached in the usual manner. Some users have found it advantageous to run disk cement into the cracks. Thick abrasive disks should be operated at an approximate peripheral speed of 5500 to 6000 feet per minute and the bearings of the machine must be in good condition. Otherwise vibration will result and this is fatal to efficient disk grinding.

TRUING ABRASIVE DISKS

While the ordinary glue-bond disk cannot be trued effectively owing to its fragile nature, the thick abrasive circles commonly used can be trued to advantage. A star-wheel dressing tool is mounted in a suitable holder and clamped to the disk grinder table. The table is fed up until the cutters just touch the rotating disk then the table is rocked back and forth until the cutters cease to cut. The micrometer adjustment screw should be used to set the cutters forward about 0.003-inch for each dressing and the operation should be continued until the disk face is true and even. For dressing the large disks used on vertical spindle machines a special device is used which incorporates a long bar over which the truing head is traversed by a feed handle.

SECTION VII

GRINDING MACHINES

Grinding machines are divided into an almost endless variety as the term is used to designate any machine equipped with abrasive means for finishing work. Broadly speaking, grinding machines fall into two classes, those for precision and rough work. Another subdivision classes machines for general and single-purpose operations. Thus a universal grinder can be called a general-purpose machine, while a grinder designed for finishing automotive-engine pistons is a special unit. Special grinding equipment is manufactured by a number of grinding machine makers, but in many plants the so-called home-made equipment is in evidence. In this section is described the grinding equipment listed as follows:

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ABRASIVE PLANE

One form of this device has a base like an ordinary wood plane and a rotary abrasive member of the pneumatic type, that is an abrasive belt is stretched over a circular yielding air sack. The abrasive member projects through the bottom of the base, an adjustment being provided to control the depth of cut. The tool is driven by a flexible shaft and used like an ordinary wood plane. Another form of abrasive plane incorporates an abrasive belt which runs over two drums with a metal backing piece between them. Power is supplied by an electric motor. As the belt traverses over the backing piece, the device is held in contact with the work and fed back and forth. Power is taken from a lighting circuit.

AUTOMATIC GRINDING MACHINES

Any grinding machine arranged to load and discharge its work is an automatic unit. Many disk grinding machines work on this principle. One type of cylindrical grinder used for finishing small parts such as roller bearing rollers is automatic. The work is fed from a hopper to a position between the centers where it is clamped securely and fed to the wheel. After grinding, the piece is discharged and the cycle repeated. One type of surface grinder is provided with means for feeding the work to the magnetic chuck, grinding it, setting down the wheel to compensate for wear and demagnetizing the work. A number of automatic surface grinders for finishing such parts as piston rings, washers, etc., are in common use. The work is fed from an upright hopper to a feed plate which carries it to the magnetic chuck. After grinding it is discharged automatically. Internal grinding machines of the semiautomatic type are in common use. Such machines gage the work as it is ground, throwing out the coarse feed and letting in the fine feed for finishing automatically. They grind to a predetermined diameter. Automatic grinding machines, of course, are practicable only in instances where extensive production campaigns warrant the expenditure of installing special equipment. Their use under favorable conditions is to be commended as it is productive of economical production results.

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AUTO-PARTS GRINDER

An auto-parts grinding machine is one designed for handling a variety of work in automobile service stations, such as crankshaft regrinding, piston grinding, etc. In reality it is a modification of a plain grinder fitted with attachments to adapt it to a variety of special operations.

BALL GRINDING MACHINES

These machines are of two types. A simple form of machine incorporates two grinding wheels, generally rubber bond, mounted one above the other. Between the wheels is interposed a feed plate with an annular slot that is set concentric with the wheels. The object of the concentric location is to assure the passing of the balls over the entire surfaces of the wheels for otherwise they would be worn locally.

A more complicated type of machine carries a large vitrified grinding wheel in a very hard grade and fine grit mounted on a horizontal spindle. The balls are fed into a *rill plate* and passing through a groove they are brought in contact with the wheel. In their second journey through they are automatically transferred to another groove in the rill plate, and so on. These machines are productive of very accurate results.

BELT GRINDER

A name applied to a machine equipped with an endless abrasive belt traveling over two drums. Such a machine is used for finishing a diversity of flat surfaces. In reality it is a refinement of the strap polisher. Usually gages are provided for locating the work straight or at an angle, while the belt can be set at any angle from horizontal to vertical.

BENCH GRINDER

As the name implies, a bench grinder is a small grinding stand designed to be mounted on a bench. Such grinders, however, often are mounted on posts or on special pedestals. Bench grinders usually accommodate wheels from 12 inches in diameter and under. If larger wheels must be used it is a better plan to mount them on a floor grinder.

CAM GRINDER

A cam grinder is a machine designed for finishing automotive-engine cams and like work. These machines are divided into two classes, those for finishing single and multiple cams. The single-cam grinder is fitted with a work head which carries a master cam for generating the desired contour of the cam in process of grinding.

Machines for finishing multiple cams are more complicated as it is necessary to provide a leader for each cam. These leaders, or master cams, are located in the workhead of the apparatus and by means of a sliding lever, the cam roll is moved from one leader to another as the various cams are finished. A lately improved machine embodies many refinements so that the number of manual operations have been reduced materially.

CAR-WHEEL GRINDER

Car wheel grinders are of two general types. That is those designed for locating a pair of wheels on an axle between centers and those for grinding wheels individually. The former type is used extensively in repair work and the latter variety in the manufacture of new wheels. A car-wheel grinder of the first named type consists of a head and a tail-stock with means for locating the work between centers and rotating it in the usual way. Two grinding wheel heads are provided so that a pair of wheels can be ground simultaneously, thus reducing the grinding time by one-half. The other type of car wheel grinder for finishing individual wheels often is of the home-made variety. The car wheel is mounted by its hole and fed against the grinding wheel by means of a cross-feed screw. Such grinders are used also on repair work to some extent, but they are not as economical in operation as the first-named type as it is necessary to take the wheels from the axle and to grind them one at a time.

CARD-CLOTHING GRINDERS

These are appliances for grinding the outer surface of card clothing as used on carding machines in cloth manufacture. After the card clothing is stretched on the card cylinder,

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the outer ends of the wires must be ground as it is essential for them to rotate in a true circle. The first operation is performed with a so-called dead-roll grinder. This appliance is a cylinder wound spirally with emery filleting cloth. The cylinder is located on the carding machine and brought against the card cylinder. The cylinder, aside from revolving, has a slight oscillating movement which aids the grinding action. A further operation is performed with a traverse grinder which embodies a solid grinding wheel mounted on a holder that traverses back and forth over a central arbor.

CARD-CYLINDER GRINDER

Card cylinders as used on carding machines are cast iron approximately five feet in diameter and four feet long. Their peripheries are finished accurately by grinding on a special machine which embodies means for locating and rotating the card cylinder on its shaft, while the grinding wheel is fed back and forth across the face. The wheel head fits a slide with a cross motion to control the depth of cut, while the wheel-head saddle traverses automatically on ways provided for the purpose. Due to the size of the rolls, card-cylinder grinding necessarily is a slow operation, but it is productive of much better results than could be attained by turning in a lathe.

CENTER GRINDERS

A term applied to a portable-type grinding attachment for finishing engine-lathe centers. They are of various types and generally they are electrically driven. Some of these tools are simple; others quite complicated. They all employ means for feeding the wheel past the center at an angle of 30 degrees, so that a 60-degree included angle is generated on the center. Belt-driven center grinders are powered from an overhead pulley or driven from the engine lathe headstock cone.

CENTERLESS GRINDING MACHINES

Centerless grinding machines are not an innovation as it is said that the practice of finishing certain cylindrical parts for textile machinery were ground in this manner in England 50 or more years ago. Centerless grinding in this country has gained great prominence during the past decade, chiefly

in the automobile manufacturing industry where production demands made efficient methods imperative.

Centerless grinders, broadly speaking, are of two types; those with feed blocks and those with feed wheels. The former type is not used extensively at the present time. In this machine the wheel is trued at an angle while the work is slid through a locating block. The difference in surface speed between both sides of the wheel draws the work through the holder. Machines with feed wheels operate on a different principle. Here a slowly revolving feed wheel guides the work past the grinding member. In one early type of machine, the Reeves, the feed and grinding wheels are located at right angles with each other so that the face of the feed wheel is used. The Detroit machine incorporates a feed wheel located under the grinding wheel. The Heim, Sanford and Cincinnati machines have the feed and grinding wheels located in the same horizontal plane. The Cincinnati machine is the only one on the American market at the present time.

In centerless grinding machines the work is placed in a feed trough which is set at an angle so that the work is conveyed by gravity to the work rest, which is located between the wheels. Centerless grinders when operated intelligently can be depended upon to produce very accurate work as regards roundness and parallelism. The usual practice is to feed the work through several times, a slight amount only being removed at each pass. Parts that can be handled to advantage on centerless machines include piston pins, push rods and a number of like parts. Large work, such as brake bands for automobiles and pistons, have been finished economically and satisfactorily on centerless machines. When it is necessary to grind a number of comparatively short pieces, such as automobile-valve cam rollers, several are located on an arbor where they fit loosely. Thus a string of several, say 10 or 12, can be finished simultaneously. As a rule work to be finished by centerless grinding should be at least as long as its diameter.

A number of centerless grinding machines are adapted for finishing work up to shoulders. In this case the work is set in a special holder which is brought into grinding position between the wheels. In the category of such parts are automobile-engine valve stems, spring-shackle bolts, king pins, etc.

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Also by means of special attachments it is possible to finish taper work.

In the selection of wheels for centerless grinding the general rule that materials of low tensile strength, such as cast iron and brass, should be ground with carbide of silicon, while alumina abrasives are reserved for grinding high-tensile-strength materials, holds good. These wheels can be bonded by the vitrified, silicate or shellac processes. The latter bond is especially adaptable for wheels for fine finishing operations. Feed wheels can be vitrified elastic or rubber bond.

Centerless grinding incorporates the negative work speed feature since the action of the machine causes the work and the grinding wheel to revolve in the same direction. At one time it was thought that the negative work speed was a detriment to economical grinding but the success attained in centerless grinding has proved this to be a fallacy.

CRANKSHAFT GRINDER

A cylindrical grinding machine fitted with means for locating crankshafts in the offset position necessary to grind the pins is called a crankshaft grinder. A machine of this type generally embodies two work heads provided with offset fixtures for locating the work. The shaft is driven from both ends through the medium of a drive shaft that connects both heads.

CUTTER-GRINDING MACHINES

These tools are of several types, a common variety being a small universal grinder. By equipping such a machine with a special geared head, spiral form cutters, spiral hobs, etc., can be ground. Another form of cutter grinder is equipped with a pair of centers between which the work can be located. Ordinary milling cutters are mounted on a special tubular holder which is slid back and forth over a round bar. This method is productive of accurate results. Special heads are required for grinding the side teeth of mills and cutters. Form-cutter grinding machines have provision for locating the work between centers on an arbor and feeding the cutter teeth past the side of a dish or saucer wheel. These machines often are in the form of attachments to fit other machines. Many special cutter grinding machines also are in use.

CUTTER-HEAD GRINDER

A special grinding machine used for sharpening the cutter heads used on woodworking machines. Means are provided for locating and rotating the head, the tooth in process of grinding being brought against an adjustable stop. A sliding table or like appliance also is provided for feeding the work past the wheel. The principle of cutter-head sharpening does not differ materially from that of sharpening milling cutters in ordinary machine shop practice.

CUTTING OFF GRINDER

A machine fitted with a thin, shellac, bakelite or rubber-bond wheel used for cutting cores, steel sections, tubing, etc. The work to be cut is located in a swinging V and in this manner brought against the wheel.

CYLINDER GRINDERS

Machines for finishing automobile engine cylinder blocks are called cylinder grinders. They incorporate means for locating the work and a planetary motion spindle that controls the depth of cut. Such machines are made both for wet and dry operation. In some types of machines the wheel head is a fixed unit while the carriage can be moved sidewise in going from one bore to the next. In other types of machines the cylinder block remains in one position while the wheel head is traversed. Another type of grinder is operated on the vertical principle, that is the block is located on the platen in its natural position, while the grinding spindle operates vertically. It is claimed for this type of machine that it is very easy to operate. In other types of machines with horizontal spindles it is, of course, necessary to mount the block on an angle-iron fixture.

CYLINDRICAL GRINDING MACHINES

In the strictest sense of the word, cylindrical grinding machines include all types for finishing round work, both internally and externally. In actual practice, however, cylindrical grinders embrace only machines used for the external finishing of round work. Such machines are of two general types, those incorporating a traveling platen and a fixed wheel head and

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those equipped with a fixed platen and a traversing wheel head. In general one design is as efficient as the other. Where the work is very heavy there is an advantage to traversing the lighter member, in this case the wheel head. Where the work is light it can be traversed without trouble. The difficulty encountered in traversing the table when grinding heavy work is that the shock of reversal of the heavy moving member must be overcome.

Cylindrical grinders are divided into several types. The most common is the so-called plain grinder designed for finishing straight and taper work. The universal grinder was designed primarily for tool-room work. It handles all kinds of work both straight and taper, internal and external and the so-called full universal machines can be utilized for surface grinding also. Modifications of cylindrical grinders are many. For example, automobile pistons and like parts are finished on a special grinder so arranged that the work can be located in place with a minimum amount of effort. Other special cylindrical grinders are designed for finishing work by feeding it toward the wheel without traversing it. Such machines work on the *plunge-cut* principle and usually they are equipped with means for moving the wheel laterally a slight distance back and forth with a slow motion to break up the wheel marks.

DISK GRINDING MACHINES

These machines are of several varieties. The simplest type carries a substantial spindle on which is mounted two steel disks, one at either end. The abrasive medium, either paper, cloth-back or heavy abrasive circles are cemented to the steel disk wheels. The work generally is held in a special fixture that is mounted on a rocking table. The rocking motion feeds the work past the abrasive disk. Such machines also are equipped with automatic feeding arrangements.

The double disk grinder carries two disks, arranged face to face, with an adjustable gap between them through which the work is fed. These machines also are equipped with automatic devices so that all that is necessary for the operator to do is to keep the feed chute full.

A horizontal disk grinder has its disk wheel mounted on a vertical spindle. The work is held on the revolving disk by its

own weight or by being weighted in place as occasion requires. The work is prevented from turning with the disk by cross members provided for the purpose. These machines also are arranged for automatic operation in which case several loading stations are provided, the work being located in special fixtures that are presented, one at a time, to the revolving disk.

Various automatic disk grinding machines have been developed during the past few years. They embody drums or feed disks for locating the work and feeding it past the disk or disks, depending on whether the machine is a single or double type.

A recently developed disk grinder consists of a hand operated device on the end of a flexible shaft. Such units are used extensively in automobile body shops, car shops, etc., for finishing metal surfaces before painting. With an appliance of this kind one man can do several times the work in a day than he can perform by hand with a file or with abrasive paper or cloth.

DRILL-GRINDING MACHINES

A drill-grinding machine is an ingenious device for generating the correct cutting angles on twist drills automatically or semiautomatically. The drill is located against a stop in a V-shape holder which is moved from a pivot in a circular path. Thus the machine generates the desired clearance automatically. Automatic drill grinders are equipped with means for feeding the V-holder back and forth automatically. Grinding on both types of machines is performed by feeding the work past the face of a cup or cylinder wheel.

FLEXIBLE GRINDER

These units consist of a power member, such as an electric or air motor, and a flexible shaft enclosed in a substantial casting that terminates in an outer bearing for housing the wheel spindle. Such machines are very useful in foundries for cleaning odd-shape castings, in die shops for finishing drop-forge dies and in fact for any purpose where it is necessary to present the wheel to the work at various angles. Some makes of flexible-shaft grinders incorporate the driving unit on a portable base so that the entire outfit can be taken from place to

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place. Other installations consist of a permanently fixed motor so that the work must be brought to the machine.

FLOOR GRINDER

A floor grinder is nothing more or less than an ordinary grinding stand as used in foundries and machine shops for snagging castings and general grinding. Such machines must be constructed substantially to reduce vibration to a minimum and the wheels should be protected by adequate guards. Some years ago, these machines were built with babbitt bearings but of late years, ball and roller bearings have been substituted with excellent results.

GAP GRINDER

A cylindrical grinding machine provided with a gap under the headstock front so that work such as locomotive piston and rod assemblies can be handled without disassembling the parts. The gap grinder is simply an adaptation of the gap lathe for abrasive purposes and it is used for similar work.

GEAR-GRINDING MACHINES

Gear-grinding machines are of two types, the formed wheel and the generating machine. The formed-wheel grinder carries an abrasive wheel the face of which is shaped accurately to grind the outline desired on the gear teeth. Three diamonds are used to form the wheel face; one for the periphery and one each for the convex-curved sides. The movement of the diamonds is controlled accurately so that the desired wheel shape always can be had. In grinding work on the formed-wheel machine, the gears are located on an arbor which is placed between indexing centers. Then the teeth are fed under the wheel with a reciprocating motion.

Generating grinders depend on mechanical means for actuating the work head to generate the necessary tooth curvatures. These consist of steel tapes and master disks or master gears and master racks. Each type of machine possesses advantages. The work is held securely on the work spindle and indexed from tooth to tooth. Some types of machines carry large wheels for grinding the gears without traverse feeding. A small wheel used under these conditions would leave a sharp curve at the bottom of the tooth which would be objectionable.

GUIDE-BAR GRINDER

A surface grinding machine equipped with a cylinder wheel and a reciprocating platen on which the work is mounted in a fixture or on angle irons. Such machines usually are called side surfacers and are used for a diversity of grinding operations. The guide-bar grinder, however, is the prototype of such machines, having been in use for over 30 years.

HAND GRINDER

A term applied to a small portable grinding machine arranged for fastening on a bench or other support. These tools also are called household grinders. The wheel spindle generally is driven by a pinion that meshes with a large spur gear, the shaft on which the latter is mounted being rotated by a hand crank. The gearing usually is enclosed. Some types of hand grinders are fitted with various devices for locating tools for sharpening. For example, it is a difficult matter to grind a tool such as a woodworkers' chisel, holding it in one hand as the other hand is necessary for supplying the motive power. With a suitable work rest, the tool can be held and guided with one hand. While these grinders were designed primarily for household and farm use, they are used in large numbers by contractors, electricians, tile setters, etc., in place of the foot power grindstones formerly used. Both carbide of silicon and alumina wheels are supplied with hand grinders. While carbide of silicon is not a steel finishing abrasive, in the strictest sense of the word, it seems to give good results on hand grinders. This may be due to the low peripheral speed at which the wheel is operated. This seldom exceeds 2000 feet per minute and it often is not over 1000.

HARROW-DISK GRINDER

A machine for grinding and polishing the disks used on harrows and cultivators. The disk is mounted on a spindle and brought against the grinding wheel. A feed arrangement usually is provided, but in the simpler types of these machines, the grinding wheel serves to feed the work. As the peripheral speeds of various sections of the disk surface vary, it is obvious that an imaginary circle passing under one edge of the grind-

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ing wheel will travel faster than an imaginary circle passing under the other edge. One serves as a brake on the other and results in a satisfactory feeding arrangement.

HOB GRINDER

As its name implies, this machine is a special grinder for sharpening hobs, either straight or spiral. It consists of a grinding wheel mounted on a horizontal spindle and a work head and foot stock, between which the work is mounted, usually on an arbor. For the grinding of spiral hobs, the work head can be geared so that the spindle turns a predetermined amount for each foot of advance. A chart is supplied with the machine which lists the gear combinations to use for generating various leads. A hob grinding machine in this respect operates like a universal milling machine when arranged for cutting spirals.

HOE GRINDER

A term applied to a machine used in making hoes and forks. It embodies a grinding wheel over which is mounted a pressure roller that is controlled by a foot treadle which enables the operator to hold the work firmly against the top of the wheel, leaving his hands free to manipulate it.

HOLLOW-WARE GRINDER

A special machine equipped with a spindle fitted with a chuck for holding the work, a grinding wheel head and means for rotating and feeding the work. The work-spindle housing is provided with a rocking motion controlled by a hand lever to feed the work past the wheel. The wheel is mounted in a holder which slides longitudinally to control the depth of cut. The various motions necessarily must be flexible to permit the wheel to conform to the shape of the stock. Otherwise an excess amount of material would have to be removed to clean up specific surfaces. Wheels for hollow-ware grinding are operated at approximately 4000 feet per minute peripheral travel.

HOME-MADE GRINDING EQUIPMENT

While there are over 200 manufacturers of grinding machinery for various purposes in the United States, the use of home-made grinding equipment is quite common. The reason for this

is not clear as it would seem that machines could be purchased from manufacturers cheaper than they could be produced locally. However, there may be logical reasons why it is practicable to construct special grinding equipment of the home-made variety.

Surface grinders for large work, such as finishing railroad frogs and switches, often are improvised from iron planers, preferably of the open-side type. All that is necessary is to equip a slow table feed arrangement and to locate a grinding wheel on the cross-rail saddle. A fair percentage of the swing-frame grinding machines in use today are home made, each master mechanic seeming to have his own ideas regarding these simple, but useful machines. Car-wheel grinders of various types often are home made also. Precision grinding machines, however, generally are purchased from manufacturers of such tools.

In some instances it may be policy to resort to home-made machines but in the majority of instances it will pay the manufacturer to consult the catalogs of grinding machine manufacturers and to obtain quotations and data on specific machines before attempting to build such tools himself.

HONING MACHINES

Honing machines are divided into two classes, those for internal and external work. Internal honing machines are used principally for finishing the bores of automotive engine cylinders. Two varieties are used, the single and multiple-spindle types. A single-spindle machine finishes one bore at a time while the multiple-spindle machine hones all the bores in a cylinder block simultaneously. Honing machines often are devised from multiple-spindle drilling machines, but the tools designed especially for honing are productive of the best results. Honing machines provide means for rotating the hones a predetermined number of degrees while they are fed through the cylinder block. During the process of honing the work is lubricated with coal oil. Modern honing machines such as the Hutto grinder embody a number of refinements for expediting the operation.

Honing heads consist of steel or aluminum bodies carrying a number of stones, four, five or more. These stones are car-

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bide of silicon, carefully tested for grade, and located in steel shoes, generally. Provision is made for keeping the hones in contact with the work through springs or other means.

The terms honing and grinding are used to designate the operation of finishing cylinder bores by the process in question, but the former term is perhaps the more widely used.

At the present time considerable progress is being made in the development of honing machines for external surfaces. The Schraner honing machine is a special unit designed for honing the main and pin bearings of automotive-engine crankshafts. The machine is provided with arms equipped with abrasive shoes or hones that are kept in contact with the work through spring action. All the bearings on one shaft are honed simultaneously. The work is lubricated with coal oil, but constant experimentation is being carried on to adapt other less-expensive lubricating mediums.

INTERNAL GRINDING MACHINES

The simplest form of an internal grinding machine is a tool-post grinder mounted on an engine lathe. Another type called a push-spindle grinder is used on precision bench lathes. The spindle of such a grinder is fed back and forth by a hand knob. Another simple form of internal grinder is the attachment used on universal grinding machines for internal work. Such a device usually is fastened to the wheel head, being driven from a pulley on the main grinder spindle.

Rapid progress made in production grinding during the past few years has resulted in the development of a number of efficient internal grinding machines, both for hand and power feed. Hand-feed grinders are used in finishing comparatively short pieces and many production engineers favor them for this work. For finishing holes over two inches deep, it is the better plan to utilize a machine with a power feed. An ordinary internal grinding machine consists essentially of a work head and a grinding wheel head. The grinding wheel head generally is mounted on a traversing carriage.

Many modifications of the above type have been developed such as the double-head grinder capable of finishing two holes in one piece simultaneously. In this case the work is located

between two wheel spindles. The majority of internal grinding machines operate on the horizontal principle, but a few vertical internal grinders have been developed that show efficiency in operation. Internal grinders also are arranged for automatic operation.

KNIFE GRINDERS

Knife grinding machines are divided into various kinds, but in general they are of two types, those equipped with disk and cup or cylinder wheels respectively. The knife is held on an adjustable work head and fed past the wheel with an automatic movement. One type of knife grinder locates the work stationary while the wheel traverses. The majority of knife grinding machines are equipped with a water supply for cooling the work, which is most essential.

As to the best type of wheel, whether disk or cup, opinions differ. The disk wheel leaves the knife slightly concave and, of course, the degree of concavity increases as the wheel wears away. By many, this is looked upon as an objection. However, to offset this, the disk wheel is comparatively free cutting. The cup or cylinder wheel leaves the knife bevel straight, or if a concavity is wanted it can be generated by locating the table at an angle. To offset the advantages of the cup or cylinder wheel, such units are not as free cutting as the disk wheel.

Knife grinding is essentially a precision operation and of late years machines designed for this purpose have been constructed with a degree of care that was not practiced some years ago.

KNIFE JOINTER

A device used for jointing the knives on woodworking planers to bring their cutting edges in the same circle. After the newly ground knives are mounted in position on the cutter head, the jointer is passed over each to remove enough metal from high sections to bring each cutting edge the same distance from the cutter head center. Both wheels and abrasive stones are used for jointing knives, and the modern types of wood planers are equipped with jointing devices invariably.

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LAP GRINDER

A term applied to a special surface grinding machine designed for grinding the ends of band saws on a taper before they are brazed. Such machines incorporate a wheel and spindle and an adjustable table for locating the work at an angle. While these grinders are used intermittently only, that is in saw-mill filing rooms, they form a very important part of the equipment, for accurate bevels on the saw ends are necessary to carry out a good job of saw brazing.

LAPPING MACHINES

These machines are of various types ranging all the way from the simple face-plate lap to the complicated units for finishing accurate gages. Face-plate laps are of two kinds, horizontal and vertical. They are made of cast iron, lead, copper or tin. Cast iron makes the most durable lap, but the other mentioned metals hold the abrasive better. In many instances a mistake is made in operating rotary laps at too great a speed.

Piston pins, round gages, etc., are lapped on a special machine embodying two cast iron laps between which the work is interposed. The work is located on a spider, one spider accommodating from 15 to 30 pieces, depending on their size. They are located at an angle from the radial line which results in a shearing action. The lapping medium is flour emery or manufactured flour corundum.

The lapping machines used for finishing flat gages such as size blocks are more complicated in design, but in general they embody means for locating the work between two rotary laps and feeding it in such a manner that the entire lapping surface is utilized. The laps must be made and maintained very accurately. The Pratt & Whitney Co. has made great progress in this line.

A novel machine is in use at the plant of the Nordyke & Marmon Co., for leveling the bottoms of aluminum-alloy crank cases. This machine is improved from a radial drill. A large bed plate is provided over which the work is caused to rotate and oscillate at the same time. Powdered glass and oil is the cutting agent.

NAIL-DIE GRINDER

A simple machine for sharpening nail dies. One end of the spindle is provided with a cup or cylinder wheel and an adjustable horizontal slide on which the work is mounted, while the other end of the spindle carries several grinding wheels with round faces of various radii. These are used for grinding out the die depressions.

OILSTONE GRINDER

A woodworking tool grinder usually equipped with several wheels such as a coarse and a fine for chisel and plane-iron sharpening, a cone wheel for grinding gouges, a wheel for general work and a leather faced stropping wheel. A carriage usually is provided with a fixture in which tools such as chisels can be located. The wheels are lubricated with coal oil which is applied to the inner or cupped portion so that it is thrown out by centrifugal action. These machines are used in pattern shops and in manual training schools.

PEARL-GRINDING MACHINES

Pearl button blanks are ground to the desired thickness on a machine technically termed a backing machine. It is equipped with a carbide-of-silicon wheel under which the work is carried by a horizontal canvas belt. The operator places the buttons on the belt by hand and they are discharged by gravity at the other end. Such machines are equipped with an exhaust hood for carrying away the dust.

Another machine called a rounding machine is used extensively. This machine is equipped with a number of chucks in which the operator places the buttons. The chucks rotate in a circular path and at a certain point in the cycle they are closed automatically. Then they are carried under the periphery of a grinding wheel. The chuck holding the button revolves so that a formed wheel generates the desired contour.

A so-called button-making machine is a complicated affair for performing several button making operations in sequence. In the operation of such a machine the blanks are placed, one

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at a time, in depressions in a feed plate. As this plate revolves the blanks pass under a carbide-of-silicon grinding wheel. From the feed plate the buttons pass to chucks that grip them automatically and feed them under turning tools. These tools are kept sharp constantly by an alumina wheel which grinds them automatically. The chucks with the buttons now pass to the drilling operation where small drills pierce the necessary holes. One hole usually is drilled at a time and when four are desired four drilling stations are passed in sequence, the button blank making a quarter turn between each. The chucks then unclamp automatically and the buttons are removed by air suction.

PISTON GRINDER

A cylindrical grinding machine adapted for the rapid finishing of automobile engine pistons is generally termed a piston grinder. Such machines usually embody means for the quick location of the work directly on the work-head spindle so that it is not necessary to place the parts between centers. A special Landis piston grinder also incorporates means for grinding the relief at the piston-pin holes after the part has been ground cylindrically. A cam movement generates the relief clearance.

FLOW GRINDER

A plow grinder is a heavy type of floor grinder designed sufficiently rigid to accommodate a comparatively large wheel, say 30 inches in diameter with a 4-inch face. The base is made sufficiently high so that the work can be presented to the under side of the wheel while the spindle bearings are long to reduce vibration. The work is held in a special cradle so arranged that it can be passed back and forth under the wheel readily.

PLUNGE-CUT GRINDER

A cylindrical grinding machine designed to finish work without traversing it. Such machines are fitted with wide-face wheels while the work is located between centers in the usual way. These machines were developed for the automotive industry, principally. Late models of plunge-cut grinders are fitted with a device for oscillating the wheel and spindle slight-

ly to break up the wheel marks on the work. Before the introduction of this refinement, the operator had to oscillate the wheel or the work himself, the member to oscillate depending on the design of the machine. Plunge-cut grinders are economical producers.

PORTABLE GRINDERS

A general term applied to any grinder that can be moved from place to place. The majority of portable grinders are electrically driven, usually by a motor ranging from $\frac{1}{4}$ to $\frac{3}{4}$ horsepower, depending on the size of grinding wheel. Portable grinders are used by hand, but the heavier units often are suspended by an overhead cable so that the operator can utilize all his energy in guiding the wheel. Pneumatic portable grinders are used for a diversity of purposes where air lines are available. These grinders are powered by both rotary and reciprocating motors.

PROFILE GRINDER

A type of machine used extensively for generating profiles on hardened work such as irregular gages. The machine embodies a grinding head and a platen mounted on a trunnion arm so that it can be moved back and forth to and away from the wheel. A master plate is located on one end of the wheel head against which a hardened pin bears. As the platen is moved sidewise, the action of the pin over the master moves the platen in and out duplicating the necessary motion to generate the outline on the work by the grinding wheel.

RADIAL GRINDER

A machine used extensively in ball bearing manufacture for generating radii on ball races. It embodies a work-holding rotating device that can be oscillated about a center which permits the wheel periphery to generate a true radius. Radial grinders also are employed for generating spherical surfaces, for instance ball ends for automobile steering parts, etc. In this case the head carrying the work is oscillated, while the wheel is provided with a concave face.

ROLL-GRINDING MACHINES

Roll grinding machines broadly can be divided into three general types: that is to say machines for finishing paper mill

calender rolls, steel mill rolls and grain rolls. Many other types of small rolls, such as those for rolling precious metals (jeweler's rolls) are finished in ordinary cylindrical grinding machines.

Grinders for finishing paper mill rolls generally embody a long bed over which the roll is mounted by its journals, being driven by a flexible coupling. Two grinding wheels are employed, one working on either side of the roll. The wheel heads hang by means of levers from a knife-edge bar so that their action in going over the roll is exactly like that of a machinist passing a pair of calipers along a piece of turned work. The object of the arrangement is to insure true rolls. These machines also are equipped with crowning devices so that it is possible to generate a crown on the roll automatically to offset its sag, through weight.

Steel-mill rolls generally are ground on massive machines that resemble ordinary plain cylindrical grinding machines. As may be imagined, heavy substantial machines are necessary. The work does not traverse, the wheel head traversing instead. Such machines have crowning devices.

Grain rolls generally are ground on the same type of machine used for finishing paper mill rolls, although smaller machines, of course, can be utilized. It is not necessary to equip these smaller machines with crowning devices.

SAW GRINDERS

Such machines are divided broadly into two types, those for sharpening wood working and metal cutting saws respectively. The so-called saw-gumming machines are used for sharpening wood saws. They are divided into two types—those for sharpening band and circular saws. A band saw sharpening machine consists of a wheel head and spindle that is moved by a cam motion to generate the correct contour to the teeth as they are fed beneath the wheel by pawls provided for the purpose. Such machines are automatic in motion. The band saw is located on rollers and is passed around two wood pulleys set horizontally. The saw is free to move as the feed pawls actuate it. The part of the saw in process of grinding is guided between an upright at the back and a bracket at the front.

A circular saw gummer does not differ from a band saw

machine except that means are employed for locating the saw on a stud. This stud is adjustable in height to take care of different diameter saws, and is provided with bushings or steps for accommodating different size holes. The saw is rotated, tooth by tooth, by feed pawls. For sharpening certain types of cut-off saws, machines are provided with a swiveling head which is controlled automatically. Thus the teeth angles are generated readily. Modern saw-grinding machines are of the cabinet type so that their working parts are protected from abrasive grit.

A special machine built on the general design of a saw gumming machine is provided for sharpening hack saw blades, small circular saws, etc. Such machines are economical to operate and they recondition saws that otherwise would go to the scrap pile.

SICKLE-BLADE GRINDER

A more or less practical device for grinding sickle bars as used in mowing machines. The wheel is comparatively wide and provided with two angles with the apex at the center. The angles thus formed serve to grind the V-shape teeth on the sickle bar. These machines are operated manually or by power.

STOVE-PLATE GRINDER

A grinding machine designed for finishing stove tops after assembly so that the surfaces of the various components will lay evenly. Some of these machines are home-made. All types embody means for locating the work and feeding it under a carbide-of-silicon wheel, or feeding the wheel over the work, according to the design of the machine.

SURFACE-GRINDING MACHINES

Surface-grinding machines are used for a diversity of purposes in tool-room and production grinding operations. They can be divided into 12 general types as follows:

1—Fixed platen with a disk wheel mounted on a horizontal spindle.

2—Fixed platen with a traversing cup or cylinder wheel mounted on a horizontal spindle.

3—Reciprocating platen with a disk wheel mounted on a horizontal spindle.

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4—Reciprocating platen with a cup or cylinder wheel mounted on a vertical spindle.

5—Reciprocating platen with a cup or cylinder wheel mounted on a horizontal spindle.

6—Rotary platen with a cup or cylinder wheel mounted on a vertical spindle.

7—Rotary platen with a disk wheel mounted on a horizontal spindle.

8—Oscillating platen with a cup or cylinder wheel mounted on a horizontal spindle.

9—Fixed platen with a cup or cylinder wheel mounted on a horizontal oscillating spindle.

10—Link grinding machines.

11—Universal grinding machines.

12—Disk grinding machines.

The first type—fixed platen with a disk wheel mounted on a horizontal spindle, is the earliest form of surface grinder. The platen is provided with a vertical adjustment which controls the depth of cut. Grinding is performed by passing the work by hand under the wheel, changing the passage angle 90 degrees occasionally. This is technically termed “spot grinding” and in the hands of an expert such a machine gives very accurate results, although it is a comparatively slow producer. These machines are used extensively for some kinds of die grinding and for other surface grinding of an intermittent nature where the amount of grinding does not warrant the purchase of a more expensive tool.

The second type—fixed platen with a traversing cup or cylinder wheel, is used largely for edging plates such as used in safe construction. The work is located on a horizontal platen, or table, and the wheel head is fed back and forth over ways, automatically. Such machines perform better work than a planer as they are operated more readily.

The third type—reciprocating platen and a disk wheel mounted on a horizontal spindle, is used extensively in tool-room and production work. The platen is actuated by power while an automatic cross-feed arrangement moves the platen saddle sidewise at each stroke of the table. The wheel housing travels vertically between uprights by means of which the

depth of cut is controlled. Graduations are provided on the elevating wheel to facilitate close settings.

The fourth type—reciprocating platen with a cup or cylinder wheel mounted on a vertical spindle, is used extensively in production grinding. Usually no cross feed is provided as the wheel is wide enough to cover the entire platen. These machines usually are equipped with magnetic chucks.

The fifth type—reciprocating platen with a cup or cylinder wheel mounted on a horizontal spindle, is essentially a production tool. The first use to which these machines were put was finishing locomotive guide bars. At the present time, however, they are used extensively on a number of production operations, finishing work directly from rough castings in less time than is required for planing or milling.

The sixth type—rotary platen with a cup or cylinder wheel mounted on a vertical spindle, is an efficient unit for production operations. These grinders are of two types. One type is operated by feeding the wheel downward to the work by hand until the wheel slide comes against a stop which controls the depth of cut. The sides of metal slitting saws, for example, can be finished economically on machines of this type. The work is located on a magnetic chuck. The larger type machine is equipped with a magnetic chuck on which the work is located. The chuck is moved forward for loading after which it is traversed to the grinding position. The wheel is fed down automatically as the chuck rotates. Such machines are rapid producers and are used for finishing parts ranging all the way from small thrust washers to automobile engine cylinder blocks.

The seventh type—rotary platen with a disk wheel mounted on a horizontal spindle, is essentially a production machine. It performs very accurate work. The parts to be ground are located on a magnetic chuck. Smaller types of these machines are equipped with a reciprocating ram on which the wheel head is mounted. Larger machines of this type resemble somewhat a metal boring machine, or vertical lathe.

The eighth type—oscillating platen with a cup or cylinder wheel mounted on a horizontal spindle, is a production machine. The work is located on special fixtures and fed back and forth past the wheel face by the oscillating motion of the platen.

The ninth type—fixed platen with a cup or cylinder wheel mounted on a horizontal oscillating spindle, embodies a fixed platen on which the work is located while grinding is performed by the oscillating motion of the wheel. The wheel spindle is mounted in a heavy yoke member which oscillates over a trunnion at the machine base.

The tenth type—link grinding machines, are essentially a special tool for finishing locomotive valve-motion links. They embody a platen on which the work is located and an adjustable bar by means of which the platen is given an oscillating motion to generate the necessary curvature. Grinding is performed by a small wheel mounted on a vertical spindle. The inherent weakness of some of the older types of these machines was that the wheel spindle speed was too slow for efficient grinding.

The eleventh type—universal grinding machines, sometimes are used for surface grinding.

The twelfth type—disk grinding machines, are essentially surface grinders as they are used for generating planes.

SWING-FRAME GRINDERS

Swing-frame grinders are used for finishing bulky castings, etc., that cannot be handled readily on other types of machines. They are of various types, stationary and portable. The ordinary type consists of a wheel and spindle mounted on the end of a horizontal support. This bar in turn is fastened to a vertical member that is located overhead. Thus the grinder can be moved back and forth over the work readily by means of two handles. The wheel spindle also is arranged so that it can be brought at an angle from the horizontal, either way, to get the wheel into confined places. The wheel usually is mounted between two bearings, while power is supplied through two belts and a jackshaft which forms the fulcrum between the horizontal and vertical supports. Another type of swing-frame grinder has a wheel mounted at the end of the shaft so that wheel changing can be accomplished readily. Some swing-frame machines are electrically driven either by belts or shafts. Portable swing-frame grinders are mounted on a base so that the grinder can be moved to the most convenient location. The

spindle bearings of swing-frame grinders are babbitt, roller or ball type. The two latter types are to be preferred for operating rubber bond wheels which must be run at high peripheral velocities to show efficiency. In general practice the wheel spindle is located so that the wheel revolves toward the operator. One type of swing-frame machine, however, has the wheel located at right angles from this position.

THREAD GRINDER

As its name implies, a thread grinder is a machine for finishing accurately screw threads, generally after they are hardened. Such a machine consists essentially of means for locating and rotating the work and a very accurate lead screw for traversing the wheel. Grinding is performed with an elastic bond wheel trued to the necessary thread angle. In some instances, two wheels are used, one to generate each side of the thread angle.

TOOL GRINDERS

A tool grinder is primarily a machine for sharpening lathe and planer tools. These machines are of various types, but they usually incorporate means for wet grinding, the water being supplied by a pump or by a trough that is moved upward by a hand lever when the machine is in use. The wheels on such machines usually are mounted between two bearings. Semi-automatic tool grinders are equipped with means for locating the work at the correct angles for grinding various tools. The use of these machines is to be recommended as a tool-crib attendant, even though he is not a skilled mechanic, can sharpen tools in his spare moments. Thus a supply of sharp tools, ground at the correct cutting angles, always can be kept on hand. Such machines are supplied with charts to enable the operator to make the various adjustments to generate the desired clearance angles correctly.

TOOL-POST GRINDERS

The tool-post grinder represents the first attempt to finish cylindrical work by grinding a half century ago and all the cylindrical grinding machines of today are refinements of this simple device. Tool-post grinders are used today for certain classes of grinding, being either belt or electrically driven. An

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ordinary tool-post grinder consists of a forked holder that fits the tool post of an engine lathe. The forked end accommodates the spindle bearings. Power is supplied by means of an overhead belt driven from a drum. An electric tool-post grinder embodies an electric motor, the armature shaft and the wheel spindle being an integral unit. The device is held in the tool post by a shank or fastened directly to the tool-post slide. Such grinders are used for a diversity of purposes in repair shops and other plants where the amount of grinding does not warrant the installation of an expensive grinder. They also can be used for finishing work that ordinarily cannot be located on a grinding machine.

TRACK-GRINDING MACHINES

These machines are used for grinding street railway tracks and are of two types. One model carries a grinding wheel which is brought in contact with the rail to be ground, while the entire device which is mounted on four wheels generally, is moved back and forth. The other model is called an abrasive plane. Its abrasive medium is a block, or rubstone, which is brought in contact with the rail and vibrated back and forth.

UNIVERSAL GRINDERS

As its name implies such a machine can be used for a diversity of purposes. As commonly understood, a universal grinder is one capable of handling cylindrical work taper or straight, internal or external. The headstock can be swiveled for face grinding also. The headstock spindle can be rotated so that grinding fixtures can be located and driven from the spindle nose. On some types of universal grinders the wheel head can be adjusted so that it is possible to grind two tapers at one setting. Some universal grinders also can be arranged to handle surface-grinding operations. Such a machine is called a full universal to distinguish it from a machine that handles cylindrical and face work only. This term is open to exceptions, however, since surface grinding can be performed on any universal grinder by locating the work in the face headstock chuck or on the headstock face plate, setting the headstock spindle at an angle of 90 degrees with the grinding wheel spindle.

VALVE-GRINDING MACHINES

A name applied to a small grinder used for refacing the valves of automobile and other internal combustion engines. It embodies a motor for driving the grinding wheel and a work-locating head, fitted with a drawin chuck for holding the valve by its stem. Various size chucks are provided to accommodate different valve stem diameters. The work head is set at an angle with the wheel axis and grinding accomplished by feeding one member past the other by a hand lever provided for the purpose. The machines used in automobile factories for seating valves with abrasive and emery also are called valve grinding machines. In reality these are valve seating units.

SECTION VIII

GRINDING PRACTICE

In this section are included a large number of grinding operations which do not fall readily under specific headings, arranged alphabetically as follows:

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ALUMINUM GRINDING

Aluminum is one of the most difficult of metals to grind as it shows a tendency to load the wheel. For ordinary rough grinding in foundries, both carbide of silicon and aluminum oxide wheels have been used successfully. Carbide of silicon wheels, in elastic bond, however, are preferred by many grinding room foremen. For the cylindrical grinding of aluminum pistons carbide of silicon in vitrified bond generally is recommended. The practice of the Oakland Motor Co. in aluminum piston grinding is to operate the wheel at a peripheral travel of 5500 feet per minute while the work speed is 20 feet per minute. A number of cutting compounds have been tried for aluminum grinding. Some operators prefer coal oil, but owing to the inflammable nature of this agent its use should be discouraged. Excellent results have been obtained with ordinary sal soda and water or any of the prepared grinding compounds. In some instances a small amount of coal oil, and in some cases machine oil is added to the mixture. Aluminum pistons can be ground by feeding the work directly to the wheel or by the traverse method. Both methods have their advantages and disadvantages so that experimentation is the only safe guide. For the surface grinding of aluminum with cylinder wheels, carbide of silicon in vitrified bond generally is used. As aluminum cannot be held by magnetic attraction it is necessary to provide special holding fixtures to locate the work.

ANVIL GRINDING

Steel faces of anvils formerly were ground under large grindstones, but present-day practice favors the use of modern abrasive equipment. After the anvil castings have been cleaned and inspected, the anvil face is ground to a true, smooth surface under a swing-frame grinder or a modern surface grinding machine of the side-surfacer type. The latter machine is considered the most efficient equipment for this operation as comparatively heavy cuts can be taken, which expedites the operation. The machines in question generally are fitted with sectional aluminum-oxide wheels while the grinding operation is performed wet.

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AUGER-BIT GRINDING

At the plant of the Job T. Pugh Co. the following processes are followed in the manufacture of auger bits: First the stock is heated and drawn out under a trip hammer. Next the part to form the screw at the end of the bit is formed under special dies. The stock is reheated for this purpose. The stock is then given the necessary spiral shape by an operation technically termed *wringing up*. This is accomplished in a machine called a *twister*. It is operated by a hand crank, one end of the bit, which has been heated previously being held rigidly, while the shank end is turned by the hand crank. After this operation a certain amount of irregularity is present. This is corrected by striking up the metal between special dies. This operation is called *crimping*. Next the head or cutting end of the bit is struck up under dies in a power press. After annealing and straightening, the outer portion is machined to the desired size by turning in a special lathe. The end of the bit then is *fitted up*, that is milled to the desired shape. The cutting edges are now filed to shape.

The bit now is ready for the first grinding process which consists of finishing the shank and the edges of the bit or spiral part. This operation is performed by hand on a 12-inch aluminum oxide wheel, 46 grit, P grade. The spirals are then ground out on silicon carbide, rubber-bond wheels, 60 grit. The two foregoing grinding operations are performed by hand and considerable skill on the part of the operator is required to turn out creditable work. The edges of the bits and the hollows of the twists then are polished on leather faced wheels set up with No. 70, 90 and 100 Turkish emery. A final polishing operation on the bit and shank is performed on a belt strapping machine with belts set up with No. 70 and 90 Turkish emery. The bits next are blued to prevent rusting and the end of the bit tempered in one operation.—K. H. Lansing.

AXE GRINDING PRACTICE

At one time, axes were ground on large grindstones, about seven feet in diameter and a foot in thickness. One stone lasted approximately three weeks. Today the grindstones have been practically replaced by manufactured abrasive wheels, the rea-

son being that this method of grinding does away with dangerous silica dust, which is a cause of the so-called grinder's consumption, while also it expedites production. In taking up the subject of axe grinding, however, it may be well to describe all the principal manufacturing processes.

An axe embodies two parts, a soft iron head, or *poll*, and a steel bit. The latter overlaps and is welded to the former. At the plant of the Warren Axe & Tool Co. axe polls are formed of soft steel under a heavy geared press. This machine shapes the stock and punches the eye. It is manipulated by two men. The bit is made of what is technically termed *overcoat steel*. It is purchased in bars and forged into a channel section in a special press. The bit and poll are brought up to a red heat and welded together under a trip hammer. This operation also draws out the the bit and it is technically termed *bit drawing*. Next the axe is reshaped in an operation called *dropping*. A mandrel is inserted in the eye and the axe, while hot, shaped between dies in a drop press.

The axe now is ready for the first grinding operation called *scribing*, which consists of grinding the outside edge all around to remove slight irregularities caused in the forging operation. This is done on a 26-inch aluminum oxide wheel operated at a peripheral travel of 5785 feet per minute. This wheel is 24 grit, U grade. It is mounted between safety flanges and equipped with a suction pipe to carry away the dust, which practice is followed with wheels used at the plant for other purposes.

Next the axe is rough ground all over on an aluminum oxide wheel, 26 inches in diameter, 4-inch face, 36 grit, R grade. This wheel also is operated at a peripheral travel of 5785 feet per minute. The operator rides a *horse* which contrivance enables him to exert considerable pressure in holding the work to the wheel. The axe is held on a bar passed through the eye and the operator keeps it in constant motion during the operation. A further finish grinding operation is performed in the same manner with a wheel in 60 grit, P grade.

Next the axe is rough polished on a canvas wheel set up with No. 80 aluminum oxide grain. The object of polishing at this stage of the process is to impart a comparatively smooth surface before the axe is tempered. Axes are hardened and drawn at the plant in question in gas-fired furnaces and considerable skill on the part of the operator is required to turn

out creditable work. If the temper is not just right the axe will not stand up when put to practical use. The axe is heated to a red heat and quenched in brine. Then the operator turns to a polishing wheel placed conveniently near him and polishes off the fire scale so he can see the color as it runs. Axes are drawn to a blue color. When the proper color is reached the axe is cooled in fresh water. The polishing wheel referred to is 14-inch, stitched canvas set up with No. 54 Turkish emery.

The final abrasive operation consists of imparting a high polish. This is accomplished on canvas wheels set up with aluminum oxide in 80 and 90 grits. The coarser grit is used for the first and the finer for the second operation. Occasionally the polisher applies oil and flour emery to the finer wheel. This results in a very high polish.

BALL GRINDING

Steel balls are formed by two processes in which the metal is worked cold or hot. In the cold forming process the balls are struck up from wire stock between steel dies in a heading machine. In the hot process the stock is formed in dies under power hammers, a number of balls usually being forged at one heat in a string.

The grinding operations must be carried out with a high degree of skill as steel balls must be accurate within very close limits. Several methods are followed in grinding steel balls. Machines such as the Schatz ball grinder carry a rubber bond wheel mounted on a vertical spindle. The balls are confined in a raceway which is set eccentric with the wheel grinding wheel so that the entire surface will be utilized. Otherwise a groove would be worn in the wheel. The balls are held against the abrasive wheel by a plate placed over them. In this operation they are ground to within approximately 0.001-inch of the desired size. The balls then are hardened and finished to size by lapping on a machine somewhat similar to the grinding machine. The difference is that the balls are lapped to size between two cast iron plates with No. 100 emery and oil.

The balls are classified by letting them roll down between the groove formed by two hardened and ground steel rollers

set at an angle. This method separates them into various sizes with a remarkable degree of accuracy.

Balls are also finish ground on Hoffman ball-grinding machines. These grinders carry a carbide of silicon wheel 24 inches in diameter with a four-inch face. The abrasive is F grit, while the grade is as hard as it is possible to make a grinding wheel. The wheel is mounted on a horizontal spindle operating from 30 to 60 revolutions per minute, depending on the size of the balls in process of grinding. A stationary plate called a *rill* is located in front of the grinding wheel. It is equipped with a number of grooves on the side next to the wheel for the accommodation of the balls. The grooves are deep enough to accommodate approximately one-third the diameter of the balls, different rill plates being provided to take care of a diversity of sizes. The balls are fed into a raceway which leads to the rill-plate grooves. The action of the grinding wheel causes the balls to rotate in the grooves until they have made nearly one revolution. Each ball then comes in contact with a device called a *picker* which switches the ball into a trough after which it is brought back again into grinding action.

The constant grinding wears grooves in the grinding wheel face. They are permitted to attain a depth equal to that of the rill grooves. The depth of the grooves in the wheel is maintained by facing off the face occasionally. After leaving the rill the balls are carried by gravity to a magazine where a conveyor raises them to a higher level so that they can be fed through the machine again. The balls thus are ground over and over again for a period of 20 hours or so. The balls are held against the wheel by a pressure of approximately 7000 pounds. Grinding is performed wet, the wheel being lubricated with coal oil.

The next process consists of polishing which is performed in wood tumbling barrels each barrel holding about 500 pounds of balls. The first polishing operation is performed with Vienna lime for a period of 24 hours. Then the balls are tumbled again in barrels with scraps of kid leather which, however, must be free of tannic acid. This imparts a high polish. The first tumbling operation removes about 0.002-inch while the second imparts a finish only.

Balls are inspected frequently for size during the manufac-

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turing operations and after the final operation for surface imperfections. They are classified by several methods. One is to use a classifying machine which consists of two hardened and ground and lapped steel rolls which are located at an angle. The distance between them is greater at the bottom than at the top. The rolls revolve and the balls are fed into the depression. They drop through as soon as the opening is large enough to accommodate them. In other instances the balls are inspected one by one under accurate dial gages.

BALL-BEARING GRINDING

The manufacture of ball bearings involves a number of precision grinding operations that must be performed with a high degree of accuracy, but owing to the perfection of the methods employed accuracy is possible even with a high quantity production. Methods followed in producing ball bearings vary to some extent but in general when making the ordinary type of annular bearing the operations in making the bearing rings, or outer portions consist of grinding the sides, rough grinding the outside diameter, rough grinding the ball race, inspection finish grinding the outside diameter, finish grinding the ball race, and lapping the race. A like sequence of operations is followed in producing the cones.

The sides of the bearing rings and cones are finished on rotary-table surface grinders equipped with magnetic chucks so that a number, as many as the face of the chuck will accommodate, are ground at one setting. Approximately 0.015-inch of metal is removed from each side. In some shops, the practice is to perform this operation on the ring and cone simultaneously after the bearing has been assembled, but this practice is not common. The objection is that the bearing is filled with abrasive grit that is hard to remove.

The outer portion of the bearing rings is finished by locating a number on a work arbor at one setting, placing the arbor between centers on a plain grinding machine. The next operation of grinding the ball race is performed on a radial grinder. The headstock carrying the ring oscillates so that the grinding wheel generates the necessary curvature in the race.

In making the cones, after heat treatment both sides are ground flat on a rotary chuck machine after which the ball races

are generated on the same type of machine as used for finishing the races in the outer rings.

The parts must be demagnetized and inspected carefully. The ball races also must be lapped to produce a high finish. This generally is accomplished with an emery and oil compound applied with the end of a soft wood stick while the race rotates rapidly. Assembly is an important operation as the parts must be fitted closely by means of selection of an outer and inner member and balls that will just fit. By this means extreme accuracy to closer limits than 0.0001-inch is not always necessary. For example, assume that an outer race was finished 0.0001-inch oversize. With an inner race of the exact required diameter the assembly would be made by selecting balls 0.0001-inch oversize. The bearings generally are given a running test in a sound-proof room. An expert tester can detect noises that would not be observed by the layman and by this means he judges whether or not the bearing should be passed as satisfactory.

BED-WAY GRINDING

Grinding of machine tool bed ways has passed the experimental stage, according to L. Sichel. Such a method of manufacturing requires a reliable system of gages, but when suitably organized, it is not difficult as very accurate gages can be ground on the machine in process of finishing. Way grinding at the present time is essentially a finishing process intended to replace scraping and nothing else. It is not intended to do away with planing or milling the quality of which is an influential factor, the same as in scraping. It is quite possible to remove economically 0.012-inch by grinding, and with much advantage over scraping in point of time, even for smaller work such as slides which may be ground in gangs with a corresponding reduction in setting up and lost time.

Way grinding was adopted in a few machine-tool plants a number of years ago and in one representative plant lathe beds up to 26 feet long are ground, together with slides and saddles, down to the last gib. There has been installed a way grinder in the plant of the Bullard Machine Tool Co. for finishing various machine-tool parts. By the adoption of way grinding this company materially reduces its finishing time, while improv-

ing the bearing and wearing qualities, as well as the appearance of the parts.

It must be understood that where accuracies of 0.0004-inch on finished products are required the built-in accuracy of the machine performing this work must well be about twice as great or 0.0002-inch, if one will be sure of the best results. This implies not only an unusual refinement in manufacturing methods of the grinding machine but also very sensitive means of alignment of all cardinal positions; since in order to produce mating parts ready for assembly the machine must be capable of generating 90-degree angles to very close limits; both in the vertical and horizontal planes as well as all other angles occurring in machine tool practice. Apart from this means must be provided on the machine for setting the wheel to very fine increments and limits in conformity with the technique or art of grinding machine ways.

In the grinding of 60-degree angles on slides it is necessary that the abrasive be of a certain kind in order to be free and cool cutting. The grinding is done dry and accurate sizes must be maintained. When it is considered that with a work speed of about 12 feet per minute and a feed of say only 0.0002-inch per double pass, ways of every width that are used in machine-tool practice can be mechanically finished, it is apparent that a machine is a better metal remover than the most hard working scraper man, even on this kind of high precision work.

Wheels used in way grinding must be porous, soft to medium grade, fairly coarse grain, and they must hold their size well while in the finishing cuts. Wheels of suitable size and shape accommodate all angles in dovetails, under-surfaces, etc., and in many instances the grinding wheel can penetrate into recesses hardly accessible to the scraper. Ready or partly assembled parts may be ground on the machine thereby avoiding distortion from later process. Beds, tables, etc., may be ground with the same facility as slides. In fact the saving in time on larger work is astonishing.

Sometimes an entire assembly of parts can be finished together ensuring a quality of alignment unknown in scraping. A case in point is the finishing of the headstock and footstock of a cylindrical plain grinder. These are assembled on a com-

mon mandril and ground as if in one piece. Machinery of the traversing work type is used on the smaller pieces, while the traversing wheel type machine is applied to the grinding of the larger parts.

BUZZ GRINDING

In the operation of a buzz grinder, the abrasive unit is a cast iron or steel disk operated at an abnormal surface speed, in some instances as high as 33,000 surface feet per minute. Traveling at this high speed, the metal disk sets up a kind of abrasive action, but in reality the metal brought in contact with the disk literally is burned away. This process has been in use for over half a century. In the manufacture of hatchets, the upper edges of the bit where it joins the poll were chamfered by buzz grinding 50 years ago. This process is followed today in the manufacture of ship augers at the works of the Job T. Pugh Co. While this method may have been efficient many years ago, it is doubtful if it can show efficiency over the abrasive wheel used for the same purpose at the present time.

CAR-WHEEL GRINDING

At one time the treads of all new chilled-iron car wheels were finished by grinding. At the present time, however, due to the fact that molding methods have been brought to a high state of perfection, new chilled-iron car wheels seldom are ground. It is, of course, necessary that two wheels on an axle be of the same size. While car wheels vary slightly in size as they are cast, they are measured accurately around the circumference and sorted in pairs of equal size. However, in a few foundries where bar-contracted chilled wheels are made it is necessary to grind the treads slightly to remove numerous small fins left by the design of the mold. In general it is stated that the grinding of a new chilled-iron car wheel takes away 10,000 miles of its life.

It does pay, however, to grind wheels that have developed flat spots in operation. One railroad company reclaimed 3500 chilled iron car wheels having flat spots from one to three inches long, with no other defects. At that time a new wheel cost \$30 while its value as scrap was \$7, which resulted in a loss of \$23 for each wheel scrapped. Tests revealed that the wheels

could be ground at a cost of 18 cents per wheel. Thus a saving of \$79,860 was affected by grinding the foregoing lot of wheels. The following data pertains to this test:

As a new car wheel was worth \$30, the cost of 3500 is \$105,000. At \$7 each, 3500 wheels have a scrap value of \$24,500. As it cost 18 cents to grind one wheel, the grinding cost for the lot of 3500 was \$630. Thus the reclaimed wheels were worth their scrap value plus the grinding cost which equals \$25,130. Subtracting this amount from the cost of \$3500 new wheels gives \$79,860. Thus it is apparent that every pair of wheels reclaimed represented a saving of about \$45.62.

It also has been stated by competent authorities that economy is shown in reconditioning steel wheels by grinding instead of turning. In turning the tread of a worn steel car wheel, it must be borne in mind that a comparatively deep chip must be taken. On the other hand, in the grinding operation just enough metal is removed to true up the tread. Chilled-iron car wheels often are ground one at a time on a machine designed to locate the wheel from its bore. However, in repair operations much better results are obtained by using a regular car wheel grinding machine which mounts the two wheels, axle and all.

Great economy is shown in the grinding of street car wheels. In this operation, which is carried out to remove flat spots, the car is run over a special grinding machine that is located in a pit. Thus the wheels can be conditioned without removing them from the trucks. One street railway company estimated that it cost from \$4 to \$5 per pair of wheels to remove flat spots when it was necessary to dismantle the truck for this purpose. The grinding time on the special grinder located in a pit under the car varies from 15 to 60 minutes per pair of wheels, depending on how much they are worn. The average time, however, is approximately 30 minutes per pair. In one instance 556 car wheels were ground in one month at a cost of 18½ cents per wheel.

CARD CLOTHING GRINDING

Card clothing as used on textile carding machines consists of a substantial stitched canvas backing covered with a staple-like projections that are inserted from the back side. The back-

ing is fastened with tacks to wooden plugs that are set into counterbored holes on the face of the card cylinder, which is a large cast iron drum. The wires are bent slightly in the direction of rotation as shown in Fig. 1. Each square foot of card

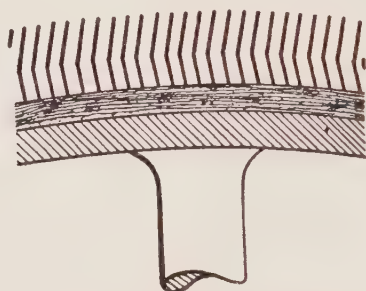


FIG. 1—THE LITTLE WIRES ARE BENT SLIGHTLY IN THE DIRECTION OF ROTATION

clothing contains about 50,000 points. They are spring-tempered steel, 0.010-inch in diameter, or No. 30 Brown & Sharpe gage. The card wires comb and straighten the cotton fibers in the operation of carding. Card clothing is attached to the main roll, to a smaller roll called the *doffer* and to other endless belt sections called *flats*.

In the manufacture of card clothing, a number of grinding operations are involved, according to Howard P. Drake. After

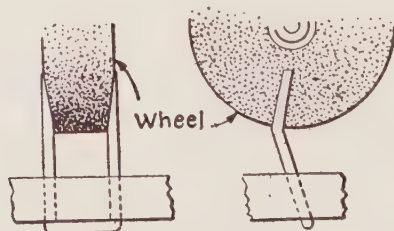


FIG. 2—PRINCIPLE OF PLOW GRINDING CARD CLOTHING WIRES

the wires have been placed in position the points must be ground. Various shapes have been used, but the so-called *plow ground* is the most popular. The principle of plow grinding is shown in Fig. 2. Thin grinding wheels, narrow enough to pass between the wires are employed for this purpose. After

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this operation the tops of the wires are ground off with wide-face wheels. The action of the wheels bends the wires slightly as it passes over them thus producing the desired grinding action.

After the card clothing is fastened in place on the card cylinder it must be ground again for the assembled card cylinder must run true within close limits. This operation is performed after the card cylinder is mounted in place. In this operation the card cylinder is rotated at a slow speed and the tops of the wires ground off with a special device called a *dead-roll grinder*. Typical dead-roll grinders embody cylinders six inches

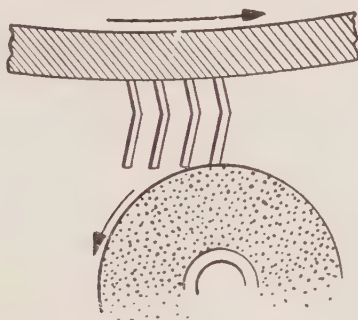


FIG. 3—GRINDING ACTION INVOLVED IN CARD CLOTHING GRINDING

in diameter and five feet long, wound spirally with emery cloth filleting. The device is attached to the card machine and it is traversed slightly by a special arrangement as it revolved. A finishing operation next is performed with a so-called traverse grinder, an attachment that fits the carding machine. It carries a cast-iron $6\frac{3}{4}$ inches in diameter and about four inches wide which is covered with emery-cloth filleting. The abrasive covered wheel traverses by a special arrangement while it revolves at a peripheral speed of about 3000 feet per minute. The grinding action is shown in Fig. 3. This device can be used to grind the clothing on the main cylinder, the doffer and the flats. This grinding method produces the desired clearance behind the wire points as they are bent slightly from their upright position as the wheel passes over them. The grinding wheel is adjusted to make a light grinding contact only and tests for the depth of cut are made only through the operator's sense of hearing. He judges the grinding action by the *swishing* sound

emitted by the wires as they are deflected by the wheel action. It takes about a day to grind a main cylinder and a doffer.

The toothed roll that carries the cotton to the card is called the *flicker in*. It must be sharp, but it seldom is ground. It is honed with comparatively fine grit carbide of silicon stones. The operation is completed with fine emery and oil applied with a hardwood stick. As a card roll must be ground once a month, it is seen that card clothing grinding goes on continuously in a large textile mill. Thus if 60 cards were operated, two would require grinding daily.

CHAIN-LINK GRINDING

In the manufacture of malleable iron chain belt, the patterns are gated for molding so that a sprue is left at the top or curved part of each link when it is broken off the gate. The sprues are removed by grinding, generally when the casting is in the hard state before annealing. The object of this procedure is to present a smooth surface on the annealed casting. Large links are ground by hand, usually by rocking the curved end over the periphery of a 20-inch carbide of silicon wheel. Semiautomatic machines are used for finishing the smaller links. Such a machine is equipped with a feed disk with a number of slots. The operator keeps the slots filled with links and as the disk revolves slowly, the links are brought under the peripheral of the wheel. Such wheels are carbide of silicon, usually about 14 inches in diameter. Machines embodying both horizontal and vertical disks are used with good results.

CHISEL SHARPENING

Due care should be exercised in sharpening wood-working chisels on a grinding wheel so as not to burn the cutting edge, according to W. C. Ewalt. Frequent dipping in water is necessary to keep the edge cool. The chisel should be held lightly against the wheel in the finish grinding operation. Care should be taken to avoid the formation of a wire edge. The angle to which the chisel is ground depends on the type of tool, that is whether a parting or firmer chisel, whether hard or soft wood is to be worked and also on the strength of the steel.

The parting chisel, which is used only by hand, is somewhat thinner than firmer chisels and a more acute angle may be given

by it. The firmer chisel, which is driven by a mallet, must be thicker and the angle larger to withstand the heavy blows. The same thing applies to chiseling hard or soft woods, the softer the wood the smaller the angle. The main difference between the parting and firmer chisels is in the shape of the handles and length of blades, the firmer being shorter. Worn down parting chisels may be used as firmer chisels. The angle to be

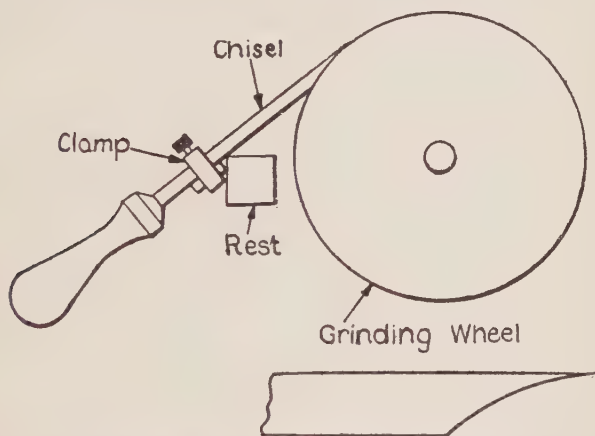


FIG. 4—HANDY REST AND CLAMP FOR CHISEL GRINDING

ground varies from 20 to 30 degrees, depending on the conditions just discussed.

It appears that chisels are easier to guide and easier to wet on an oil stone if they are hollow ground. This may be accomplished by holding the chisel in the same angle on the stone and moving the chisel from side to side. A piece of iron may be clamped to the face as shown in Fig. 4 to facilitate placing the chisel back in the same place each time after dipping it in water to cool. As the grinding leaves a rough wire edge, it is necessary to whet the chisel on an oil stone to obtain a fine cutting edge. It is here that the advantage of having the chisel hollow ground may be seen, since it is much easier to sharpen it to the same angle as ground. One is more likely to whet to a greater angle if it is ground straight instead of hollow since a few strokes across the oil stone will sharpen it at the angle wanted if hollow ground, while it takes far more whetting to wear away the full length of a straight ground angle.

In whetting, the oil stone being flat, straight and in good condition, is given plenty of oil. The heel of the angle is first placed on the stone and the handle is raised until the heel and edge lie flat on the stone. This may be seen by the action of the oil at the edge of the chisel as it exudes from under the edge of the chisel when it is raised. When the position of the tool on the stone is fixed, the chisel should be moved back and forth across the length of the stone, care being taken that the chisel does not rock. The rocking may be prevented largely by holding

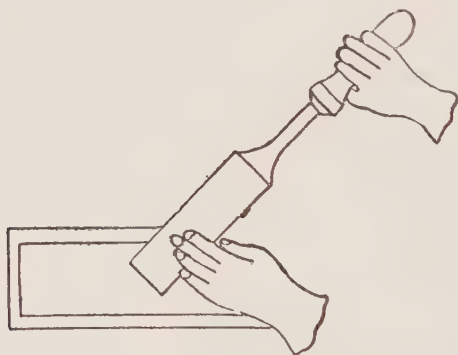


FIG. 5—CORRECT METHOD OF WHETTING
A CHISEL

the chisel on the stone diagonally as shown in Fig. 5. This position allows a natural movement of the elbows when moving them back and forth, clearing the body and keeping the edge from being spoiled by rocking.

After a few strokes the chisel should be examined for the wire edge, which is turned over by whetting, by feeling across the flat side with the thumb. The chisel has been whetted enough when this wire edge is felt. The edge is removed by turning the chisel over on the flat side and moving it across the stone while held perfectly flat. The chisel then is reversed to the original positions and a few strokes made in that way. This may be repeated several times, the edge then being lapped upon the band or stropped on a piece of leather. Some test sharpness of the edge by feeling it with the thumb while others see if it is sharp by holding up to the light. The chisel with a beveled edge is preferred as it looks neater, is lighter

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and may be used in corners and angles where it is impossible to use the square edge tools.

Excellent results in chisel sharpening also are derived through the use of the so-called oilstone grinders, as such machines are equipped with devices for locating and guiding the work. The use of these appliances, however, is confined generally to large plants so that the patternmaker and other woodworker must exercise considerable ingenuity to get along with the equipment available in the everyday shop.

CONNECTING-ROD GRINDING

The connecting rods of automotive engines are subjected to two grinding operations generally. The surfaces where the rod and its cap join are finished on surface grinding machines with cup wheels or on disk grinding machines. This insures a good joint that will function correctly. The holes in both ends often are finished by grinding although grinding of the large hole which is babbitt lined is not always considered necessary. However, in some instances these holes are ground to generate working seats for subsequent operations. The holes in the upper ends of the rods are ground to insure accuracy for the piston pin bushing or the piston pin itself, depending on the design. The machine used for grinding the holes is an internal grinder fitted with raising blocks to enable it to swing the work.

COPPER GRINDING

Copper, without a doubt, is the most difficult of all metals to grind satisfactorily. For the rough general grinding of copper castings, carbide of silicon wheels in vitrified bond have been used with good results. Such wheels should be operated at a peripheral travel of approximately 5000 feet per minute. An exhausting system should be installed to carry away abrasive dust. The system will pay for itself in a short time as large quantities of metallic copper can be reclaimed.

In taking up precision grinding of copper, the rolls used in the rotogravure process of printing form an excellent subject. These rolls are cast iron shells mounted on steel shafts with an electroplating of copper over the iron about $\frac{3}{8}$ -inch thick. These rolls vary in size according to the kind of equipment they

are designed for, but diameters from 8 to 20 inches and lengths from 40 to 90 inches are common. Grinding of these rolls goes on continually, for after each printing the design must be ground away to make way for a new one. The impressions etched on the roll are about 0.005-inch deep. These must be ground away and a high polish imparted. Manufacturers of printing machinery supply special grinding machines for this work while the grinding is performed with natural stones, so-called Tam O'Shanter and Water of Ayre. These are Scotch products. After grinding, the rolls are given a high polish with rouge paper, charcoal or fine grit hones. The high polish is quite necessary for slight imperfections would mar the etching from which the printed impression is made.

Of late years numerous experiments with modern abrasives and cylindrical grinding machines have been conducted in the grinding of the rolls in question and while the grinding wheel is yet to be developed that will finish the rolls without the supplementary polishing, considerable success has been attained. The wheels used are carbide of silicon in very fine grit, 100 being a favorite. The grade is medium soft to soft. It is claimed that the modern method reduces the grinding time by 50 per cent and that it produces rolls that are round and true within close limits.

CUTLERY GRINDING

Cutlery grinding is a general term applied to abrasive operations followed in the manufacture of scissors, shears, knives of various kinds, razors, etc. Shears and scissors are of two kinds—solid and steel laid. Solid shears and scissors are made from one kind of steel, while the laid variety consists of a soft steel back to which a tool steel cutting edge is welded. One variety is as good as the other, according to some authorities. The scissors or shears are shaped under drop-forge dies and after trimming to remove the flash they are subjected to the first grinding operation which consists of grinding the bows and backs. For this work silicate-bond wheels generally are employed. These wheels are from 30 to 46 grit in a medium grade. They are mounted near the floor so that the workman can sit on a stool. The wheel runs toward the operator. Considerable skill is necessary in this operation as the work must be guided wholly by hand. Cutlery grinders, as a rule, are men

who have devoted a lifetime to the industry, thus they become highly proficient through practice. The work is paid for generally on a piece work basis.

The parts then are drilled, tapped, counterbored and tempered after which they are ready for the second grinding operation which consists of grinding a slight concave on the inside of the blades. This is done on large diameter silicate-bond wheels or on natural grindstones. The operator used a lever to hold the shear blade in contact with the wheel, while the degree of concavity, of course, is governed by the wheel diameter. Next the parts are assembled and a slight amount ground from the inside of the bows so that the points will come together correctly. Then the outside of the blades is ground, either on grindstones or silicate-bond wheels. The workman sits before the wheel and guides the work by hand. Next the bows are finish ground on silicate wheels. The cutting edges are sharpened by hand on a carbide of silicon or alumina wheel.

Polishing follows next for an attractive appearance is necessary. This is performed in canvas wheels setup with Nos. 140 and 180 emery grain, although in some shops manufactured alumina abrasives are used. The operator sits in front of the wheel which rotates toward him. Nickel plating follows after which the cutting edges are sharpened on a fine-grit wheel, usually 80. Both carbide of silicon and manufactured alumina wheels are used for this purpose. Next the nickel plate is buffed on canvas wheels with white buffing compound. While the foregoing is a general outline of shear grinding practice, the operations differ in many plants for what may be considered good practice in one shop is not permitted in another.

In the manufacture of table knives, another important branch of the cutlery business, the steel first is forged under trip hammers and then rolled between dies. Superfluous material then is trimmed away in dies after which the blades are tempered. In some shops, however, tempering follows the first grinding operation. The principle abrasive operations are grinding, glazing and finishing. Grinding the sides of the blades generally is done on special grinders, called Hemming machines. The work is held in a special fixture and fed automatically past the face of an elastic-bond cylinder wheel. Glazing generally is performed on a wheel set up with No. 120 emery. The finishing or

buffing operation is done generally on walrus-hide wheels set up with 180 emery. On high grade work further finishing is necessary, it being performed on wheels set up with F and FF grain. This final polishing imparts a finish that is quite proof against rust. The processes followed in the manufacture of pocket knives do not differ materially from that followed in making table cutlery. However, the final finish generally is imparted with on wheels set up with crocus.

Table forks are blanked out under power presses. They are finished between the tines on narrow canvas belts set up with 120 emery. A second polishing with F emery generally follows. The shanks are finished by polishing on wheels set up with 120, 180 and F emery generally. A final finish often is imparted by buffing with fine abrasive.

Exacting grinding operations are involved in the manufacture of razors. Many years ago they were hand forged as they are today in some localities. The drop forge process, however, is used to quite an extent in this industry. Grinding operations consist of roughing on grindstones or large silicate-bond wheels. After tempering the blades must be concaved or hollow ground. This is a precision operation that requires considerable skill. The curvature of the wheel face determines the amount of concaving. After tempering the blades, they must be polished on set-up wheels with fine emery. The final honing or sharpening is performed on rotary hones. In general, it can be stated that the manufacture of cutlery of all kinds has been expedited greatly by the introduction of manufactured abrasive wheels. The silicate-bond wheel is of especial value as it is rapidly replacing the natural sandstones which have been used for generations.

CUTTER SHARPENING

Milling cutters should be sharpened frequently. Otherwise an abnormal amount of metal must be removed from the teeth when grinding becomes imperative. Milling cutters can be sharpened on universal grinding machines or on special cutter grinders. The latter machines are preferred in the majority of cases. The first factor to consider in the sharpening or ordinary milling cutters is the degree of clearance. The Brown & Sharpe Mfg. Co. give the following data on this subject:

The angle of clearance depends upon the diameter of the

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cutters and must be greater for small cutters than for large ones. The clearance on the teeth of plain milling cutters should be from 4 to 5 degrees for cutters over 3 inches in diameter and from 6 to 7 degrees for those under 3 inches, and the land at the top of the teeth should be from 0.002 to 0.004-inch wide before the clearance is ground. The clearance of the end teeth of end mills should be about 2 degrees and it is well to have the teeth a little hollowing, letting them be 0.001 or 0.002-inch lower near the center than at the outside, so that the inner ends of the teeth will not drag on the work. If the clearance of the cutter is too great, vibrations are likely to occur in operation, and this is something to avoid.

The Brown & Sharpe Mfg. Co. supply the following data which shows how far below (or above) the wheel center to set the guide finger for generating 5 and 7 degree clearances:

Diameter of cutter, inches	5-degree clearance, inches	7-degree clearance, inches
1½	$\frac{3}{84}$	$\frac{5}{84}$
1½	$\frac{3}{84}$	$\frac{5}{84}$
1¾	$\frac{3}{84}$	$\frac{5}{84}$
1⅞	$\frac{1}{18}$	$\frac{5}{84}$
2	$\frac{1}{18}$	$\frac{5}{84}$
2⅛	$\frac{1}{18}$	$\frac{5}{84}$
2¼	$\frac{1}{18}$	$\frac{3}{24}$
2⅜	$\frac{1}{18}$	$\frac{3}{24}$
2½	$\frac{1}{18}$	$\frac{3}{24}$
2⅝	$\frac{1}{18}$	$\frac{3}{24}$
2¾	$\frac{5}{84}$	$\frac{7}{84}$
2⅞	$\frac{5}{84}$	$\frac{7}{84}$
3	$\frac{5}{84}$	$\frac{7}{84}$
3⅛	$\frac{5}{84}$	$\frac{7}{84}$
3¼	$\frac{5}{84}$	$\frac{7}{84}$
3⅜	$\frac{5}{84}$	$\frac{7}{84}$
3½	$\frac{5}{84}$	$\frac{1}{8}$
3¾	$\frac{3}{24}$	$\frac{1}{8}$
4	$\frac{3}{24}$	$\frac{1}{8}$
4¼	$\frac{3}{24}$	$\frac{1}{8}$
4½	$\frac{3}{24}$	$\frac{1}{8}$
4¾	$\frac{3}{24}$	$\frac{9}{84}$
5	$\frac{3}{24}$	$\frac{9}{84}$
5¼	$\frac{3}{24}$	$\frac{9}{84}$
5½	$\frac{7}{84}$	$\frac{9}{84}$
5¾	$\frac{7}{84}$	$\frac{9}{84}$
6	$\frac{7}{84}$	$\frac{9}{84}$

Ordinary milling cutters are best sharpened on a holding device as shown in Fig. 6. It consists of a hollow arbor that slides over a straight bar that can be held in the grinding machine head. The cutter is held between two collars, A and B,

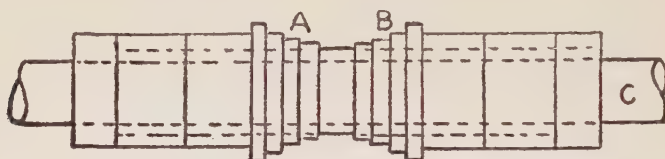


FIG. 6—ARBOR AND COLLARS FOR MILLING CUTTER SHARPENING

which are provided with several steps to accommodate different size arbor holes. The arbor with the cutter in place is slid along the bar, *C*, the tooth in process of grinding being supported by the guide finger. If the cutter was held on an ordinary arbor between centers it is obvious that if the arbor was sprung (and most arbors are) the cutter teeth would not be concentric with the hole. Thus a few high teeth would be compelled to do all the cutting. In the grinding operation the wheel can run toward the tooth back, as shown in Fig. 7 at *A* or toward the front of the teeth as shown at *B*. It is claimed that the method shown at *A* is liable to result in burning the tooth edges if care is not exercised. However, in using the method shown at *B*, the tendency of the wheel action is to pull the cutter away from the guide finger, so that care must be exercised in holding the cutter, otherwise the teeth will be gouged and ruined.

In grinding, the cutter should be fed past the wheel with a fairly rapid motion and a slight depth of cut as this operation is generally performed dry. Wet grinding of milling cutters is to be recommended when possible as the cooling solution keeps down the frictional heat. It is a good plan to make the

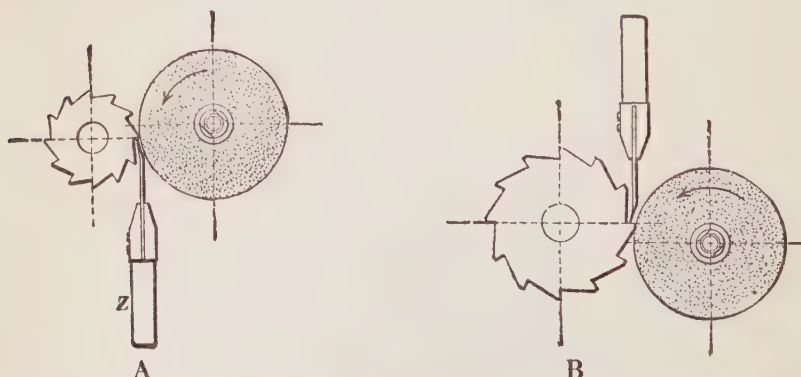


FIG. 7—TWO METHODS OF SHARPENING AN ORDINARY MILLING CUTTER

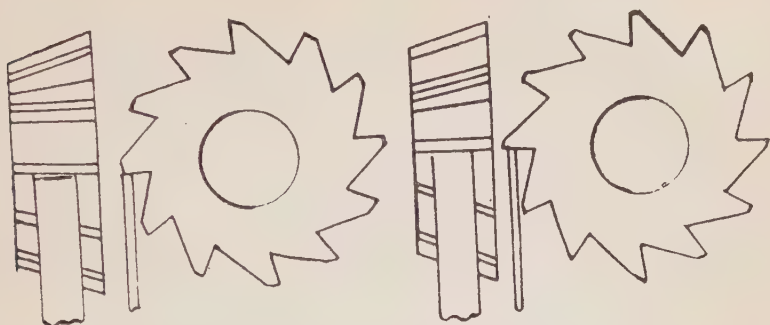


FIG. 8—INCORRECT AND CORRECT SETUPS FOR SHARPENING ANGULAR CUTTERS

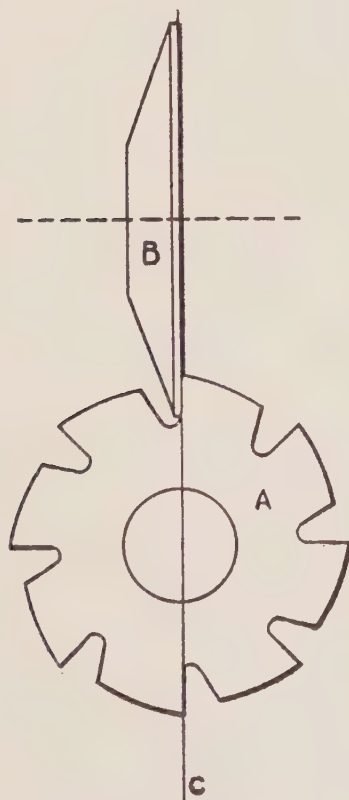


FIG. 9—TYPICAL SETUP FOR SHARPENING A FORMED CUTTER

first tooth ground with chalk and to grind the teeth evenly and carefully until the cutter has been gone around once. The wheel may wear a little in going around the cutter so that in taking the finishing cut, the depth of cut should be very slight. This will help to insure a round cutter.

A spiral milling cutter is ground in the same manner as a straight one. In this case the guide finger is adjusted to conform to the tooth face. Considerable experience is necessary to sharpen spiral cutters correctly. In sharpening angular cutters, the cutter center must be in line with the teeth to avoid errors. Thus the clearance must be obtained by adjusting the grinding wheel axis above or below the cutter center, or ad-

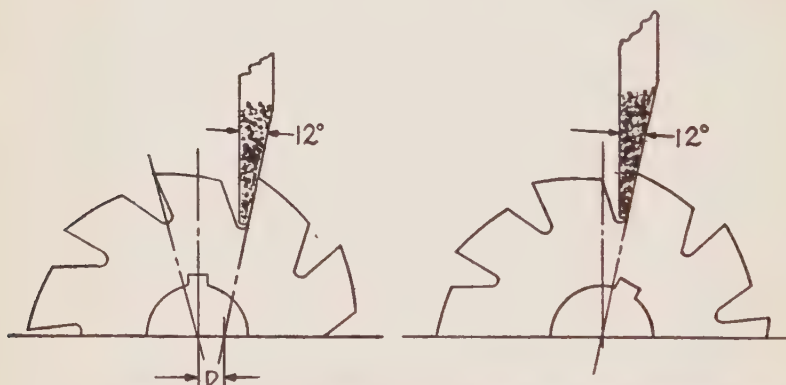


FIG. 10—ARRANGEMENT OF WHEEL AND WORK FOR SHARPENING OFFSET FORMED CUTTERS

justing the cutter head in a like manner, depending on the design of the machine. In Fig. 8 are shown correct and incorrect methods of locating angular cutters for grinding.

The side teeth or ordinary milling cutters are sharpened by locating the cutter on a stub arbor which is set in the universal head of the cutter sharpening machine. For ordinary cutters, a cup or saucer wheel is used. For end mills it is considered good practice to use the periphery of a small wheel. Both taper and straight shank end mills can be sharpened between centers, but a better plan is to locate them in a special holder which is held in the cutter head. Thus if the cutter is sprung it is corrected in grinding to bring the teeth concentric with the shank.

Formed cutters are sharpened by locating them on an

arbor and feeding the teeth faces one at a time past the flat side of a saucer wheel. This setup is shown in Fig. 9. Here it is shown that the center line, *C*, aligns the face of the wheel, *B*, with the teeth of the cutter, *A*. The grinding can be performed in a machine provided for the purpose or the cutter on its arbor can be located between centers on a surface grinding machine. Light cuts must be taken to avoid burning the teeth. If possible, the grinding face of the wheel should be away from the operator so that he can observe the cutter in

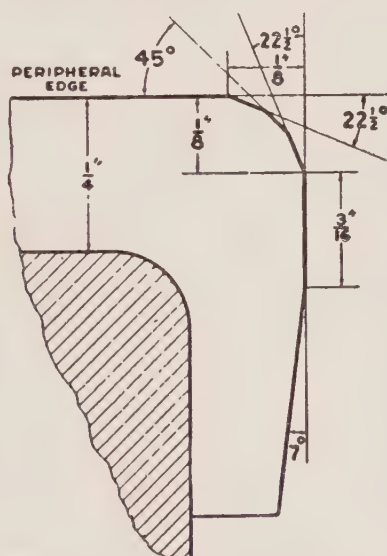


FIG. 11—METHOD OF SHARPENING A
LARGE INSERTED TOOTH MILL-
ING CUTTER

process of grinding readily. The teeth are ground one at a time until the cutter has been around once. Then the cutter is set up a little by turning it radially and another cut taken around, and so on until the cutter is sharp.

During recent years the practice of using rake or offset form cutters has become quite common. In this case the amount of offset in thousandths of an inch always is stamped on the cutter. In Fig. 10 is shown a setup for sharpening "curvex" spiral offset cutters made by the Pratt & Whitney Co. These cutters are made with either radial or offset teeth. They are sharpened on a cutter grinder on an attachment made for the purpose or on an ordinary universal cutter grinder equipped

with a leader for generating the necessary spiral. When sharpening these cutters care must be exercised to maintain the correct relation between the wheel and the cutter. When grinding rake or offset tooth cutters, a line passing along the cutting surface of the grinding wheel should pass ahead of the cutter axis by the distance, D , measured on a horizontal plane. When sharpening radial-tooth form cutters a line passing along the cutting surface of the grinding wheel should intersect the axis of the cutter arbor. All spiral form cutters are marked with the lead angle which information is essential in grinding.

The method recommended by the Cincinnati Milling Machine Co. for sharpening large inserted-tooth cutters is shown in Fig. 11 and, as the illustration shows, the corners are broken at three angles. A special machine is used for grinding the cutters. In setting up the machine for this operation with the cutter spindle in a vertical position, the dials are set at zero and the swivel housing swung around perpendicular to the grinding wheel face so that the face of the mill is mounted on the spindle and clamped in position in line with the vertical face of the wheel. Most mills have the blades set in a body in such a way that an effective rake or under cut of from 10 to 15 degrees is produced on the periphery. Peripheral clearance is obtained by rotating the swivel housing of the machine which supports the cradle. Obviously it is necessary to rotate this housing an amount equal to the number of degrees of under cut, plus the number of degrees of clearance desired. For example, on a mill in which the blades are set to give a 15-degree under-cut, would require swiveling the housing 25 degrees in order to obtain a 10-degree clearance. The grinding of the clearance is accomplished by moving the grinding wheel up and down over the blades. To get the back, or secondary clearance, the housing is swiveled 3 degrees more and the teeth ground so as to leave 1/16-inch land on the cutting edge. In grinding the corners, the saddle is adjusted on the bed away from the grinding wheel enough to permit swinging the cradle carrying the mill down 22½ degrees. The reading is taken from the dial near the crank. The reading is taken from the dial near the crank. The cradle can be clamped in this position by a clamping bolt. With the angle adjustment of the swivel housing the same as for grinding the periphery, the first corner angle of 22½ degrees

is ground. The 45-degree angle is next obtained by locating the mill at an additional $22\frac{1}{2}$ degrees setting in the manner previously described. The $67\frac{1}{2}$ -degree angle complete in the corner is ground exactly the same way.

To grind the face of the mill the saddle is moved still farther out on the bed to allow for swiveling the cutter into a horizontal position. Inasmuch as most face mill blades are set in a body at an angle, in order to give effective space rate, it is necessary to adjust the swivel housing in an amount equal to the sum of the face-rake angle, plus the clearance angle desired. For example, on a mill having a 7-degree face rake, the swivel housing must be adjusted 17 degrees in order to obtain a 10-degree face clearance. Less clearance is obtained by a corresponding smaller angle. The last operation is to grind the back clearance leaving about $1/16$ -inch land behind the cutting edge. This is done by rotating the swivel housing 3 degrees beyond the first clearance angle setting. The face of the blades can be backed off toward the center, leaving any desired amount of face contact by dropping the axis of the mill below the horizontal and repeating the foregoing operation. In all of the above settings it is desirable that the relative position of the wheel and the blades being ground be such that the wheel contact with the blades produces wheel marks which appear perpendicular to the cutting edge.

The importance of using sharp milling cutters at all times should not be overlooked. When the teeth become slightly dulled, the cutting edges are rounded. Under these conditions an abnormal amount of power is required for operation. The finish left by dull cutters never is satisfactory while their use also generates a large amount of heat which is liable to warp the work.

The process of sharpening reamers does not differ radically from that followed in sharpening milling cutters and end mills. However, reamers generally are sharpened by feeding them past the face of a cup wheel. If a disk wheel is used, the hollowness of the teeth sometimes causes chattering. Reamer teeth generally are stoned after sharpening.

CUTTING STEEL AND TUBING

Small pieces of steel tubing, etc., often can be cut to advantage on a cutting-off machine. The action of the wheel leaves

smooth edges which is not always the case when a band or hacksaw is used. One disadvantage to the abrasive method is the waste of material through the necessarily wide kerf, but other advantages more than offset this.

CYLINDER-GRINDING PRACTICE

Automobile-engine cylinders generally are finished by grinding, although the cylinders for a few makes of popular-priced cars are finished by reaming only. Preparatory to grinding the cylinders are rough and finish bored, leaving approximately 0.015-inch for grinding. This allowance, of course, varies with the diameter of the bore. In the grinding operation the block is located on an angle iron fixture of a special machine designed for this work. These machines are equipped with a planetary spindle to control the depth of cut. The majority of cylinder grinding machines are of the horizontal type although one make incorporates the vertical principle.

Some operators prefer to finish one bore completely before moving to the next. It is better practice, however, to rough grind all the bores in one block to within approximately 0.002-inch of the desired size. Then a finishing cut is taken through each bore. In some instances a number of blocks are rough ground and set aside for a few hours before taking the finishing cuts. This allows the work to cool off, but it necessitates careful aligning of the work when it is relocated for taking the finishing cut.

Cylinder bores can be gaged with inside micrometers, but a better method consists of using a dial gage mounted on a special block with a curved base so that the device can be passed entirely through the bore. By this means very slight errors can be noted readily. As a rule if the average cylinder bore is accurate within 0.001-inch for roundness or parallelism it is close enough for practical purposes. However, more exacting tolerances are followed by many automobile manufacturers.

The majority of cylinders are ground dry, a dust pipe being fitted to the back of the bore in process of grinding to carry away the abrasive dust. Sometimes water at city pressure is run through the water jacket to keep down the heat generated by friction. A few makes of cylinder grinders are arranged for wet grinding. All factors considered, this practice is to

be recommended, but why it is not followed more universally is a question of conjecture. The cooling solution keeps down frictional heat and also it aids materially in producing an excellent finish.

DIE GRINDING

Dies for blanking out metal and other substances must be sharpened at frequent intervals, for if they are permitted to become abnormally dull, an excess amount of metal must be removed to recondition them. Comparatively long dies should be ground with tapered faces so that a shearing cut results. If, however, the stock instead of the punching forms the product,

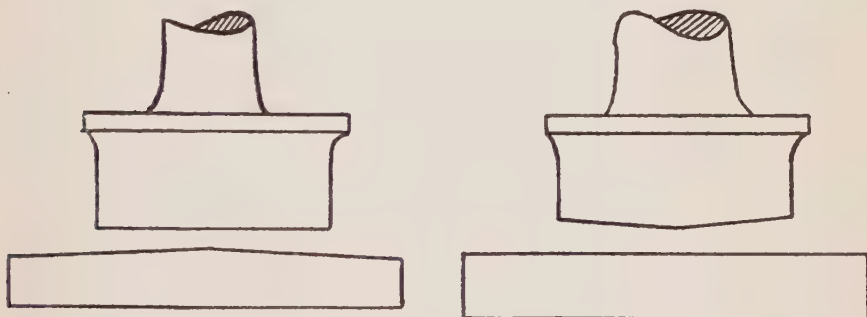


FIG. 12—AT THE LEFT IS A SHEARED DIE WHILE A SHEARED PUNCH APPEARS AT THE RIGHT

the punch must be sheared. The principle of die shearing is shown in Fig. 12. At the left is shown a sheared die and at the right a sheared punch. In some instances the shearing is done just the opposite of that shown; that is, the lowest point is at the center.

The simplest method to follow in die grinding is to use a machine equipped with a wheel and an adjustable work table. The die is fed back and forth under the wheel by hand resulting in the so-called *spot grinding*. It is obvious that a fixture must be provided for holding the punch by its shank. Angular locating fixtures also are necessary for holding the die and the punch for generating the sheared faces. However, if the grinder is equipped with an angular adjustment on the table, these fixtures are not necessary.

Surface grinding machines as used for die grinding are of various kinds as follows: Machines with a reciprocating platen

and a cylinder wheel mounted on a horizontal spindle; machines with a reciprocating platen and a cylinder wheel mounted on a vertical spindle; machines with a reciprocating platen and a disk wheel mounted on a horizontal spindle; machines with a rotary platen and a disk wheel mounted on a horizontal spindle, and machines with a rotary platen and a cylinder wheel mounted on a vertical spindle. Any of these machines can be used for die grinding, but with the first named type it would be necessary to mount the work on an angle iron. The dies can be strapped to the platen or they can be held on magnetic chucks. The latter method is preferable. Rotary table grinding machines always are equipped with magnetic chucks.

Dies can be ground dry or wet, but the latter method is to be preferred as it reduces the frictional heat which permits the taking of deeper cuts. In grinding dies on a machine with a disk wheel and a reciprocating platen, the wheel should be fed down until it just touches the work. Then it should be set down again from 0.001 to 0.002-inch, depending on whether the work is ground dry or wet. It is obvious that a light cut is necessary in dry grinding. The traverse feed should be about 1/32 to 1/16-inch for each complete reversal of the platen. The die surface should be ground until the cutting edges are clean and sharp.

When using a machine with a rotating platen and a cylinder wheel all that is necessary is to locate the die not too near the center of the chuck and proceed to grind in the usual way. If the machine has a rotary platen and a disk wheel, the die should be located so that its opening comes at the chuck center to permit a space for the wheel to feed into at the end of the wheel-head stroke.

Die grinding does not differ essentially from ordinary surface grinding. The points to observe are that the depth of cut must not be great enough to draw the temper from the work and that the die is located correctly in place. The type of wheel to use is an alumina abrasive in a medium-coarse grit, 24 to 46, depending on the nature of the work, and a soft grade.

DRILL GRINDING

Before the general introduction of semiautomatic drill grinding machines, the sharpening of twist drills could be entrusted

to an expert only. The drill lips were ground by guess work generally, although a clearance angle of 59 degrees as recommended by Professor Sweet was the most satisfactory. The semiautomatic drill grinding machines in use today have solved the problem of correct drill angles. The operation of such a machine is simple as all that is necessary is to locate the drill in the holder, bring it against the wheel face and rock it back and forth to generate the clearance angle. Then the drill is turned over and the other lip sharpened. In regular shop practice, it is a good plan to have drills ground by one of the tool crib attendants in his spare time. Thus a supply of sharp drills always is on hand. This method is productive of excellent results as it assures correctly ground drills. Drill grinding should be performed wet when possible as dry grinding is liable to draw the temper.

In operation, every portion of a twist drill lip travels in a helix of its own, according to data submitted by the Worcester Polytechnic institute. No two of the helices are of the same diameter but all are of the same pitch as all parts of the drill advance equally. The clearance at any given point on the cutting lip is determined by and bears a constant relation to the tangent of its own individual helix. Therefore, near the point of the drill where the helices are smaller, their pitch remaining the same, these tangents form more acute angles with the axis of the drill than when the diameters are large, as near the outer point of the lip. To grade the clearance properly along the drill lip from the point to the periphery and to curve the back side of the cutting edge so that maximum endurance and strength consistent with free cutting are preserved at all points, it is necessary that every point on the cutting lip should pass the grinding wheel in a path similar to that in which the drill travels when at work. As the portions of the drill lip near the point travel in comparatively short paths, this condition should exist while the drill is in process of grinding. In Fig. 13 the lines, *C*, *D*, represent the axes around while the drills are rocked while being ground; *A* and *B* represent the radii of the arcs through which different portions of the drill lips swing in front of the grinding wheel, *A*, being near the drill point and *B* near the outer corner of the lip. From the fore-

going it is evident that where A is shorter than B , the conditions are correct.

By the angle of lip clearance is meant the clearance necessary to take care of the feed. This is similar to the clearance necessary for all cutting tools. This clearance, however, varies for each point on the cutting lip and it gradually increases as the center is approached. The reason for this is shown in Fig. 14. The feed, X , per revolution, being constant, the path described by

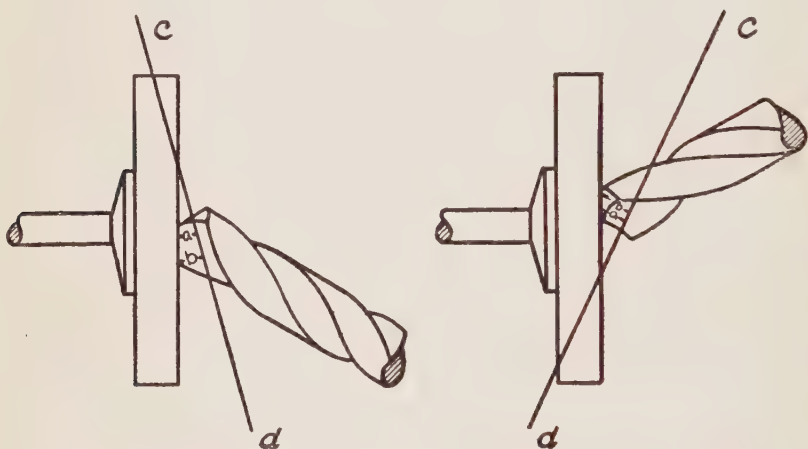


FIG. 13—PRINCIPLE INVOLVED IN SHARPENING TWIST DRILLS

A and B will correspond to the helical lines shown. As the vertical distance, X , that each point moves per revolution of the drill will be the same, the angle of the smaller helix will be greater than the larger one. The helix angle in each case indicates the minimum clearance necessary at the particular point for a feed per revolution equivalent to the distance, X .

Many users of drills do not appreciate the full advantages to be gained by grinding the points of drills or point thinning as it is called. Comparatively little action cutting takes place near the drill point. At this place the rotary movement is relatively slow, but the advance is considerable so that heavy pressure is necessary to force the drill into the work. This is particularly noticeable in operating comparatively large drills as they have thick webs. Thus, point thinning is common practice, especially when using large drills. Point thinning should be done on a machine provided for the purpose.

GRINDING PRACTICE

According to William Sellers & Co. it is impossible to set a fixed rule as to the amount the web should be thinned in pointing, as it is influenced by the shape and angle of the flutes as well as by the kind of material that is drilled. Also the speed and feed must be considered. However, the following data give point thicknesses for various size drills which have given good results under average conditions:

Diameter of drill, inches	Thickness of point, inches
$\frac{1}{2}$	$\frac{1}{16}$
$\frac{3}{4}$	$\frac{5}{64}$
1	$\frac{3}{32}$
$1\frac{1}{2}$	$\frac{1}{8}$
2	$\frac{3}{32}$
$2\frac{1}{2}$	$\frac{1}{8}$
3	$\frac{7}{32}$

In drilling medium-carbon steel with a drill $1\frac{9}{19}$ inches in diameter, measuring $\frac{9}{32}$ -inch at the point, it was found that by reducing the thickness of the point to $\frac{1}{8}$ -inch, the pressure required for drilling was reduced 66 per cent, while the horsepower required was reduced 27 per cent. The experiment was repeated with over twice the original feed, in which case the horsepower required for the thick-point drill was increased 145 per cent, while on the thin-point drill it was increased only 110 per cent. The following data gives a comparison of the work performed with pointed and unpointed drills. These data were furnished by William Sellers & Co., and the tests were made with a $1\frac{11}{16}$ -inch drill operated at 155 revolutions per minute, drilling soft steel.

FEED 0.15-INCH PER REVOLUTION

	Power required, amperes	Pressure exerted, pounds
Web unpointed	45	8,500
Pointed web, $\frac{1}{8}$ -inch thick	35	2,056
Pointed web, $\frac{3}{32}$ -inch thick.....	32	1,940

FEED 0.021-INCH PER REVOLUTION

Web unpointed	55	8,800
Pointed web, $\frac{1}{8}$ -inch thick.....	$39\frac{1}{2}$	2,950
Pointed web, $\frac{3}{32}$ -inch thick.....	39	2,592

FEED 0.033-INCH PER REVOLUTION

Web unpointed	70	12,000
Pointed web, $\frac{1}{8}$ -inch thick.....	$50\frac{1}{2}$	4,312
Pointed web, $\frac{3}{32}$ -inch thick.....	49	3,800

The foregoing tests were made with a $1\frac{11}{16}$ -inch drill operated at 155 revolutions per minute. The material drilled was soft steel, $1\frac{1}{4}$ -inches thick.

A great amount of trouble and expense can be saved by the users of twist drills if a little more care is exercised regarding the proper grinding of the points, according to W. M. Gladding. Improper point grinding is not only costly but efficient results cannot be obtained unless the proper angle of point, lip clearance and angle of chisel point is obtained. Drill-point grinding

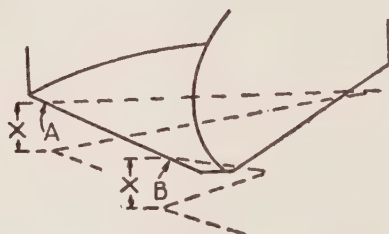


FIG. 14—TWIST-DRILL LIP CLEAR-
ANCE

machines located in tool rooms and throughout the plant are excellent steps toward getting the correct point grinding on drills. It is very difficult and requires a great deal of experience to grind a point by hand that will give the desired results without too much loss of time.

The standard drill point has an included angle of 118 degrees, lip clearance of 12 to 15 degrees, and the angle of chisel point 130 degrees. This point has been found best suited for drills engaged on the average class of work used under general conditions. Different grades of material at times require a modification of this point for best results. Hard material may require a blunter angle of point while softer materials may require a more acute angle. The following may be found of value to those having several different kinds of materials to drill:

Steel rails	135 degrees included angle 10 degrees lip clearance
Drop forgings Brinell hardness 250	125 degrees included angle 12 degrees lip clearance
Tool steels	125 degrees included angle 12 degrees lip clearance
Cast iron and Machinery steels	118 degrees included angle 15 degrees lip clearance

GRINDING PRACTICE

Brass	118 degrees included angle 15 degrees lip clearance Stone face of cutting lips to reduce angle of spiral.
Copper	100 degrees included angle 15 degrees lip clearance

The following figures show the maximum point pressure and torque for a 1-inch forged type high-speed drill used in brass, cast iron, machinery steel and tool steel. A feed of 0.020-inch per revolution was used in every instance with speeds best adapted for the material being drilled.

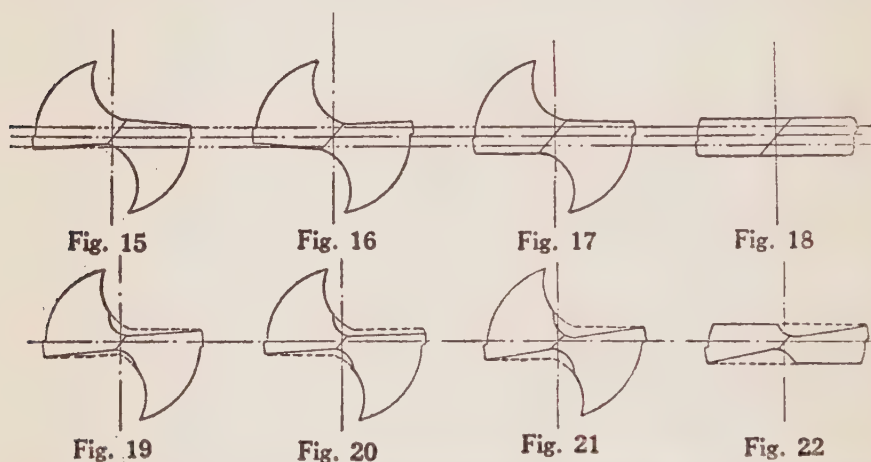
Material	Speed	Feed per revolution, inches	Lubricant	Point pressure, pounds	Torque inch, pounds
Brass	540	0.020	Lard oil	500	280
Cast iron	387	0.020	None	1100	440
Machinery steel	287	0.020	Lard oil	1200	560
Tool steel	198	0.020	Lard oil	1900-2100	1010

The breaking down of the outer corners of cutting lips and wearing of the margin are the most common troubles experienced with drills and is caused by running at too fast a periphery speed for the material being drilled. In drilling high-grade tools, steels or material of a dense nature the speed at which the drill is run and the penetration per revolution must be given careful consideration. Cutting lips not of uniform length will drill a hole oversize and cause excessive wear on the margin of one lip. Insufficient lip clearance will cause the drill to rub on the heel or back edge of cutting lip and will not cut, causing undue strain on the machine and often breaking the feeding mechanism or splitting the drill up the center of the web. Too much lip clearance will weaken the drill at its cutting edges causing same to crumble when entering the work. The successful use of drills is dependent more upon the proper grinding of the points than any one thing. Of course a careful consideration of speeds and feeds must at all times be used. If users of drills will give a little more attention to the condition of the point grinding throughout their plants considerable saving could be obtained.

More is demanded of the modern high speed twist drill than of any other perishable small tool used in manufacturing, according to E. C. Oliver, and this in spite of the fact that it often works under most adverse conditions. No other tool operates with the point of support so far from the cutting edge.

No other tool is required to rid itself of its own cuttings and no other tool has received so little attention in regard to properly conditioning the point so that it can cut freely and with as little strain to its own structure as possible.

However, the gradually increasing feeds and speeds required in high production manufacturing have made it necessary to increase the web thickness in drills to withstand the added strains and has also made it imperative that drills be ground with proper clearance angles and proper point angles and that



FIGS. 15-22—VARIOUS FACTORS PERTAINING TO CORRECT DRILL GRINDING

every precaution be taken to produce a practically perfect cutting edge. This is very important.

Drill grinding machines have solved the problem of producing automatically a point having proper angles of clearance and point so that both lips will cut the same amount and the strains of drilling be evenly distributed. Such machines, however, cannot take account of the structural variations of drills and while they do to a considerable extent, eliminate the effect of the thick web by a peculiar undercutting at this point, still it is the practice in most shops to further thin the web to reduce the feeding pressure.

High speed drills, especially those of the twisted variety, are subject to slight inaccuracies which may affect the size of hole drilled even though the point may be accurately ground. These inaccuracies are shown in the accompanying illustrations.

Fig. 15 is an end view of a drill with web out of center. Fig. 16 shows a drill with the lips out of index. Fig. 17 is a drill with an abnormally thick web and Fig. 18 is one of the flat twisted type with the web as thick as the land at the outside diameter. The conditions shown in Figs. 15 and 16 are seldom noticed, due to the difficulty of measuring. The error shown in Fig. 17 usually is corrected by grinding a notch at the center of the drill on each side of the web to reduce the thickness. If this is done by hand, there is no certainty that the web is central and it destroys the top rake of the cutting edge as far out on the lip as the notch extends. The drill in Fig. 18 requires considerable metal to be ground away to reduce the web and a very high degree of skill is required to produce a point with proper top rake. Errors such as the foregoing should be corrected on a special drill point thinning machine. Correctly pointed drills are shown in Figs. 19, 20, 21 and 22.

FILE GRINDING

Comparatively large files are made from blister steel but the smaller and fine files are cast steel, according to A. Stringer. Various ingenious machines have been contrived for cutting the teeth of files, but these have not hitherto succeeded so well as to supersede file making by hand. After the file has been cut it must undergo the process of tempering. In the United Kingdom this is said to be well effected in the following manner: Salt and ale grounds or well dried chimney soot is spread over the file to preserve its surface from oxidation during the process. It is then uniformly heated in a coal or charcoal fire to a cherry red color and in its removal from the fire it is suddenly quenched in cold and pure spring water.

Files made many years ago were similar to those made today in form and machines were sometimes used for cutting the teeth. High grade steel was used, in fact so good was the steel from which the files were made that it would harden satisfactorily in pure water. Modern alterations and improvements in the manufacture of files have taken place which enable Sheffield filemakers to produce, at the present time, a better and more efficient tool than ever before and Sheffield methods of production are at least abreast of those of foreign competitors. With regard to the material from which files are produced,

the modern steelmaker is assisted at the present time by his laboratory and efficient testing methods to enable him to maintain that high standard of quality which is so essential for good files. For fine files good crucible steel gives the best results.

The hand forging of files has now been almost superseded by the use of machinery and considerable efficiency has been attained in both the use of machine hammers and rolls. File annealing has been brought to a high level of efficiency by the use of pyrometers and recording instruments and by the benefit of research work at the Sheffield university. A coal fire furnace is to be preferred for this operation. It should be of the bridge type, protected on the outside by stout cast iron plates and the interior of the furnace maintained at a uniform temperature and allowed to cool down before the blanks are removed.

From time immemorial the Sheffield file grinder has successfully ground files of all shapes and sizes by hand and it was only in recent years that his place has been taken by a machine which not only does more than he could possibly do, but it grinds files quicker and more uniform and with less personal risk to the grinder. One of the first machines which was constructed for this work was known as Bright's grinding machine, and the originators of this machine deserve a debt of gratitude from filemakers for the introduction of machinery for this operation. Later developments of file grinding machinery, particularly of the Oxley type possess many advantages over the earlier machines. It was possible on modern file-grinding machines to produce four times the quantity of work to the quantity which was formerly produced by hand. The output of such machines on 14-inch files, for example, is six dozen per hour, while on small files an output of 400 dozen files per day had been reached.

Sheffield has been frequently criticized for not keeping up to date in machinery and methods. It is, therefore, pleasant to state that orders for file grinding machinery have been received from France, Germany, Switzerland, Italy, Spain, Russia, Holland, Japan and the Colonies, thus establishing the Sheffield file-grinding machine a desirable and efficient tool for the purpose.

The question of the adoption of the abrasive wheel for file

grinding had been put up to the Sheffield manufacturers but up to the present time, no machine has been designed which will satisfactorily take the place of the present sandstone grinding machine. For the past ten years abrasive wheel manufacturers have claimed to have discovered the correct wheel for this job, but when it was put to the test the machine had invariably been blamed for the failure, and nothing else had been offered to replace it.

It would be possible to design and produce an efficient machine using the abrasive wheel for this work, and while it might not be faster in the rate of production than existing machines, it would certainly improve the conditions of work for the operator. Research would have to be carried out before such a machine could be perfected, and undoubtedly Sheffield is the place where such research work should be carried out, as the local conditions have an important bearing on the ultimate success of the machine.

Much attention has been paid to the question of the application of the abrasive wheel. A number of files recently were submitted to a prominent firm of grinding machine makers, and they successfully ground the files. They were parallel files, and ground on a magnetic chuck. After grinding, the files needed no stripping, and there were no wasters. If all files were parallel there would be no difficulty, but the variety of shapes and thicknesses caused the designers much trouble. A machine has been designed to overcome these difficulties, but its cost appears to be prohibitive to Sheffield manufacturers at the present time. The introduction of mass production methods and the application of automatic machinery would tend to reduce the cost of production per unit of files. Severe competition exists among Sheffield filemakers but co-operation among the filemakers might enable them to overcome some of the difficulties.

FORK, RAKE AND HOE GRINDING

Forks and hoes generally are made of a good grade of steel as they must withstand rough usage. Abrasive operations in the manufacture of these products serve a twofold purpose. They expedite production and assure an attractive article that will meet with a ready sale. Hay, garden and other varieties of forks are forged and welded by ingenious methods after

which they are bent to shape and the tines formed by rolling between rotary dies. Hoes also are formed by the rolling process.

At one of the plants of the American Fork & Hoe Co. the rolling process has been in use for over half a century. Preliminary operations in the manufacture of forks and hoes consist of heating the stock and drawing it out to the desired shape.

An ordinary rake is punched between dies from hot stock, the stock being manipulated so that waste is reduced to a minimum. Forks of various kinds are made from bar stock which is welded and then bent to conform to the desired shape. The roughly formed fork then is rolled while hot between rotary dies equipped with depressions for forming the tines to the correct shape. Hoes are made by upsetting the stock between dies and then rolling it between rotary dies. The rolling process removes the hammer marks and refines the stock so that it takes the desired temper. The rotary dies are expensive to construct and maintain, but they are economical in the long run as excessive grinding and polishing would be necessary to remove the hammer marks if this method were used.

Operations preliminary to grinding and polishing eye or planters' hoes consist of forging the stock, punching the eye and rolling out the blade. These operations all are performed on special machinery designed or adapted for the purpose. The hoes are polished on a Hawes hoe grinder equipped with a compressed canvas wheel set-up with No. 46 emery. The wheel revolves away from the operator while a pressure roller over the hoe is operated by a foot treadle to hold the tool firmly against the wheel. An exhaust pipe is provided to carry away the abrasive dust. In polishing the back of the hoe it is necessary to hold the work in a pair of long-jaw tongs. The wheel used is the same as that employed for polishing the back. In some instances where a particularly fine finish is desired, a further operation on wheels set up with No. 100 emery follows. This, however, is not the regular practice. The operation of racing the bevel consists of sharpening the edge of the tool so that it will cut. It is performed on a floor grinder equipped with an aluminum oxide wheel 20 inches in diameter, 2-inch face, 36 grit, operated at a peripheral travel of approximately 5500 feet

per minute. A special rest is employed which is set close to the wheel so that the work cannot catch. Considerable skill must be exercised in performing this operation as the work is guided wholly by hand. A skilled operator, however, can race the bevels very rapidly and an examination of the finished work reveals a smooth even cut.

In polishing ordinary garden hoes, the tool is held in a pair of special tongs and one side of the back is polished at a time. The machine is a Hawes hoe polisher fitted with a compressed felt wheel set up with No. 46 emery. Two operations, roughing and finishing are involved, finishing being done with No. 80 emery. In polishing the face of this type of hoe it is held against a narrow abrasive belt. The belt runs over a small roller so that the polishing can be brought close to the shank without interference. This is a special machine built by the American company, while the belt is canvas, set up with No. 50 emery.

A stitched canvas unit set up with No. 46 aluminum oxide is used for polishing hoe shanks. The work is held against the wheel by spring pressure, while it rests in a depression provided for the purpose. The operator turns the shank by hand, while a foot treadle is employed to take the tension off the work for removal. The bevels on these hoes are raced on a Hawes floor grinder equipped with an aluminum oxide wheel 18 inches in diameter, 2½-inch face, 24 grit. This wheel is operated at an approximate peripheral travel of 5500 feet per minute and the work is guided against the wheel by hand.

Considerable ingenuity has been shown in the design of equipment for polishing the tines of forks. The machine is a Hawes polisher equipped with a rawhide belt set-up with No. 46 aluminum oxide. The belt travels approximately 4000 feet per minute, while the tine in process of polishing is held in place with a hand-driven finger. The operators develop great skill in manipulating the work to bring all parts of each tine in contact with the belt. As the work is fed crosswise of the belt it is given a twisting motion back and forth. In this manner one-half of each tine can be finished. Then the work is turned over for finishing the other sides. Several of these polishers are in operation and each is fitted with an individual blower to carry away the abrasive dust. The dust collector

is located outside the building and the exhaust pipes are carried through the brick wall to the main pipe of the collector.

In polishing ordinary garden rakes, the work is held in a special fixture which is supported on a rest and fed back and forth over a 20-inch compressed felt wheel set up with No. 46 aluminum oxide. The purpose of this operation is to remove slight irregularities and to impart a finished appearance. The fixture for holding the work consists of a hard-wood block to accommodate the piece, while two handles are fitted to the back for guiding it.

FROG AND SWITCH GRINDING

Manganese steel is so hard that it cannot be worked with cutting tools and for this reason makers of manganese equipment are dependent on abrasive practice. At the plant of the St. Louis Frog & Switch Co., after the castings are shaken out in the foundry, they are annealed. Manganese cast steel, unannealed is too hard for track work. In annealing, the castings are raised to a white heat and quenched in cold water. The tank used for this purpose is 10 feet deep and of ample capacity to assure an adequate supply of water at the correct temperature. The next step is to straighten the castings. This is accomplished by heavy hydraulic presses. The operator uses a straight edge to try his work. It is necessary to exercise considerable care, for the straighter the work, the less amount will have to be ground away in the finishing process. This reduces the grinding time.

An open-side planer equipped with a grinding attachment is used for finishing street-railway crossings. One end of the crossing is strapped to the platen while the other end is fastened to an outboard support which travels over rollers. The purpose of this support is to take the overhand strain which might pull the platen off its ways. The piece is first carefully aligned so that the part technically termed the "line," which is the depression in which the wheel flange runs, travels straight under a given point as the platen travels back and forth. Then the top of the rail is ground off true and flat. This grinding is done wet. The wheel used is aluminum oxide, 18 inches in diameter, 2½-inch face, 2-inch hole, 8 grit, run at 1200 revolutions per minute. This results in a peripheral speed of 5654 feet per minute. In this operation the work travels under the

wheel at a speed of 26 feet per minute. Approximately $\frac{1}{8}$ -inch is removed by this operation, the depth of cut for each pass over the work being $\frac{1}{64}$ -inch.

After the top is ground, the next operation is to grind out the line. The face of the wheel employed is trued to the desired contour and fed down to the work. The wheel is aluminum oxide, 18 inches in diameter, $1\frac{1}{4}$ -inches thick. The grit and grade is the same as that of the wheel employed for surfacing. One-eighth inch is allowed for finishing. With the line ground out, the crossing is reset and another top and line ground and so on until all four rails and lines have been finished. A crossing 12 feet long requires 10 hours for grinding. Grinding the lines is an exacting operation because where they cross, one cut must not be deeper than the other. This is because in going over the crossing, the flange of the car wheel travels on the bottom of the line so that the wheel tread does not touch the rail. This eliminates the decided jar experienced when a wheel bearing directly on the rail face goes over the gap in the crossing. Gages are used in grinding the lines and in cases where they do not meet exactly at the crossing, that is where one line is a few thousandths of an inch below the other, the difficulty is remedied by grinding out by hand. Other work on this crossing consists of grinding the ends square and removing any irregularities on the surfaces where the fish plates bear. These are hand grinding operations that do not differ from similar operations on other track equipment that will be explained later.

One type of angular crossing for steam roads has manganese inserts at the crossing points, the lines being ground with a hand grinder. The crossing is assembled on the floor, the various parts being held in place by heavy clamps. Later, the fish plates are bolted in place as these members hold the crossing together. The machine used for this operation is a portable electric grinder, equipped with an aluminum oxide wheel, 10 inches in diameter, 1-inch face, 20-36 combination grit, operated at 1800 revolutions a minute. This results in a peripheral speed of 4712 feet a minute. The grinder is suspended by a chain hoist. By this means the operator is enabled to set it at the proper height. The manganese sections ground are $3\frac{1}{2}$ feet

long. Approximately $\frac{1}{8}$ -inch is removed and the grinding time for the four sections is five hours.

In finishing switches, a number of interesting grinding operations are involved. In squaring the ends, the grinding is performed with a portable grinder equipped with an aluminum oxide wheel, 12 inches in diameter, $2\frac{1}{2}$ -inch face, 8 grit, driven at 1800 revolutions a minute. This gives a peripheral travel of 5653 feet per minute. For this operation, stub wheels are used. The new wheels are 18 inches in diameter and are used in surfacing the tops of rails, as previously described. The surface ground is 6 x 9 inches. Three ends are surfaced on each switch, the production time for one switch being one hour. Approximately $\frac{1}{8}$ -inch is removed from each end.

For grinding out the floor, heel, and circle where the switch point fulcrums a radial drill equipped with a special grinding wheel head is used. The wheel used is aluminum oxide, 5 inches in diameter, $2\frac{1}{2}$ -inch face, 16 grit, equipped with a lead center carrying a 1 x 8 left-hand thread. This wheel operates at 1800 revolutions a minute. Grinding is performed both with the periphery and the face of the wheel. As the face of any grinding wheel is comparatively slow cutting when compared with a wheel that cuts on its periphery only, the grinding operation is somewhat slow. In removing approximately $\frac{1}{8}$ -inch of stock the grinding time is four hours. This is a semi-precision operation as a good fit must be formed for the head of the switch point. Gages are used in determining the correct dimensions.

For finishing inside of the double end of the switch base where the fish plates bear, a small wheel on an extension arbor is used. The machine used is a portable electric grinder, equipped with an aluminum oxide wheel, 4 inches in diameter, 1-inch face, 20-36 combination grit. This wheel is run at 1800 revolutions a minute which gives a peripheral speed of 2261 feet per minute. Approximately 2 square feet of surface are ground, removing $\frac{1}{16}$ -inch. The grinding time for this operation is one hour. For grinding the open ends where a larger wheel can be used, the grinding time is materially reduced.

The lines on switch mates, that is the path in which the wheel flange runs, are finish-ground by hand. The machine used is a portable electric grinder equipped with an aluminum

oxide wheel 10 inches in diameter, 1-inch face, 20-36 combination grit, operated at 1800 revolutions a minute. This speed gives a peripheral travel of 5654 feet per minute. The line ground is 12 feet long. Approximately 1/64-inch is ground out. The grinding time for this operation is two hours.

Switch tongues, namely the movable part of switches, require a number of grinding operations before they are fitted in place. One operation consists of grinding the sides. The machine used is a portable electric grinder equipped with an aluminum oxide wheel, 10 inches in diameter, 1-inch face, 20-36 combination grit, driven at 1800 revolutions a minute, imparting a peripheral speed of 5654 feet per minute. To fit a tongue in a switch takes approximately four hours of grinding. Both sides as well as the top and bottom must be ground. Also, the fulcrum is smoothed so that it makes a free fit in the switch. A typical switch tongue is 6 feet long and approximately 1/8-inch of metal is removed in grinding.

GEAR GRINDING

Gear grinding is a latter-day development brought about by the use of alloy and heat treated steels. The pinions used in operating the gates of the Panama Canal are alloy steel, finished by grinding. The demand for silent running automobile transmission gears also has furthered the practice of gear grinding.

In grinding alloy steel gears from rough castings, sufficient metal should be left to generate the teeth of the desired size and pitch diameter. Usually such an operation is not a production one so that plenty of time can be allowed. In the manufacture of automobile transmission gears, however, which is a production operation in the strictest sense of the word, idle time must be reduced to a minimum. Latter day practice dictates that the gears should be cut or hobbled in one operation, then heat treated and ground. Sufficient material must be allowed for grinding but not an excessive amount, as this would prolong the operation unnecessarily. Care must be exercised to keep the wheel free cutting at all times and also the grit and grade must be suited for the work.

After grinding, the gears must be tested to make sure that the teeth are of the correct outline and that the gear is of the desired pitch diameter. A number of interesting and intricate

devices have been perfected for this purpose. While the chief use of gear grinding machines is among automobile manufacturers, machine tool builders are beginning to give these machines attention as they are capable of reducing production costs materially in the manufacture of gears used in feed and speed boxes.

In the operation of a machine employing the formed-wheel method designed by the Gear Grinding Machine Co., the grinding wheel mounted on the machine spindle, is dressed with diamond tools as shown at the left in Fig. 23, while the view at the right shows the position occupied by the wheel in the grinding operation. In truing the wheel, the movement of the dia-

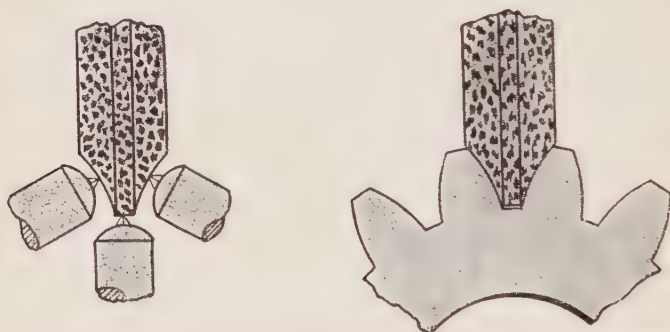


FIG. 23—AT THE LEFT IS SHOWN THE METHOD OF DRESSING A WHEEL FOR GEAR GRINDING WHILE AT THE RIGHT THE CUTTING ACTION IS SHOWN

monds is controlled by accurately formed templates. These templates are six times the size of the tooth to be ground and through a pantagraph mechanism they direct and control the motion of the diamonds.

The gears to be ground are located between centers on an arbor directly connected with an index head located on the machine table. The table is hydraulically operated, the formed wheel passing between the gear teeth, grinding both sides and the bottom of the space at each stroke. The gears are indexed one space at the end of each table stroke by an index mechanism which is operated hydraulically through a large plate having accurately ground gashes in its periphery. The hydraulic drive for the table gives wide range of speeds.

After the gears are mounted on the machine, a roughing cut is made completely around the gear, and repeated when

necessary, until the teeth are approximately 0.001-inch over the finish size. The grinding wheel then is trued and the finishing cut taken. Cluster gears, with a minimum space of one inch between them, can be ground as shown in Fig. 24. When finishing gear teeth by the formed-wheel method it is not necessary to cut the blanks to close limits. The general practice is to rough-cut the teeth, leaving them from 0.008 to 0.013-inch thicker than the finished size. It is claimed that the method in question finished gears within a limit accuracy of 0.0001-inch. Gears from $\frac{1}{4}$ to 10-inch pitch diameter with faces up to 10 inches and from 4 to 24 diametrical pitch and of any pressure can be ground on the machine in question. This type of machine also is employed for spline grinding, in which the foregoing method is followed.

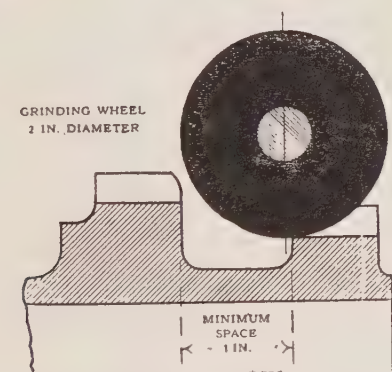


FIG. 24—HOW CLUSTER GEARS ARE GROUND WITH A FORMED WHEEL

One model of the Lees-Bradner gear grinder employs a flat-face grinding wheel of larger diameter set at an angle to represent the side of a basic rack tooth of the gear tooth system. By rolling the gear past the grinding wheel an involute tooth profile is generated. The movement of the work head to give the necessary motion is controlled by two steel tapes under tension which wind and unwind over a so-called master or pitch disk, which must be of the same pitch diameter as that of the gear to be ground. The grinding wheel is trued by a diamond dressing tool mounted on an arm that swings in a plane perpendicular to the wheel axis. The work is mounted from its bore, held on centers or from its shank on which it rotates in the completed mechanism, thereby correcting all inaccuracies.

The latest model of the Lees-Bradner machine, however, employs a master gear and a master rack instead of steel tapes and a pitch disk. The machine is built in right and left-hand models to facilitate the handling of gears made integral with their shafts, such as the stem gear which drives the countershaft in a typical automobile transmission. The machines are paired for the grinding of the driving side of the teeth on one machine and the coasting side on the mating machine. Thus both surfaces are located from the same setting.

The Fellows gear grinder is equipped with involute cams which act against straight-edges to generate the tooth curvature, while the National machine employs this principle also. The Maag grinder carries two wheels and is equipped with a pitch disk that takes care of a considerable range of pitch diameters. Another feature of this machine is the automatic wheel truing device. The work is held between centers and fed past the wheels so that a combination of reciprocating and generating motion is afforded. The Pratt & Whitney grinder carries two wheels mounted on a vertical spindle, while the generating mechanism consists of a master gear and rack. The wheels are 24 inches in diameter, while the grinding surface utilized is a narrow band at the edge of each wheel. Each wheel is mounted independently of the other so that it can be adjusted in two directions. In operation, however, the wheels have no motion except rotation.

The Garrison gear grinder embodies a cone-shaped wheel which is carried on a ram that is moved back and forth after the manner of a metal-working shaper. The wheel travels through one tooth a space at a time grinding both sides simultaneously. Meanwhile the gear is rolled back and forth under the wheel something after the manner in which the Maag grinder operates. As the ram is actuated the work table carries the blanks past the grinding wheel. The rolling motion of the gear blank is controlled by a master gear and rack.

HOLLOW-WARE GRINDING

The manufacture of hollow ware is confined largely to prisons although a few representative plants are established elsewhere. Hollow ware is a term applied generally to cooking utensils such as spiders or skillets, kettles, pots, etc. The object of grinding the inside of hollow ware is to give it a presentable

appearance so that it can be displayed attractively for sale. Also a smooth interior is necessary for cleansing the articles thoroughly after use.

In hollow ware grinding, the wheel conforms to the shape of the work as shown in Figs. 25 and 26. Here a skillet, *A*, and a kettle, *C*, are shown. By setting the travel of the grinding wheel head at an angle, the bottom of the article and the face can be ground at one operation. At *B*, the operator starts the cut at the center, *F*, and feeds the wheel to the point, *G*, when the wheel is fed out of the work to finish the surface, *H*. The angle of the side of the work to be ground determines the angular position of the wheel head. At *C* a round-bottom kettle is shown.

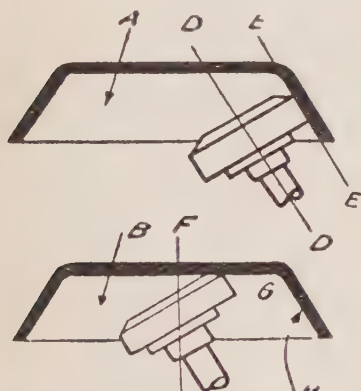


FIG. 25—PRINCIPLE EMPLOYED IN GRINDING A SKILLET OR SPIDER

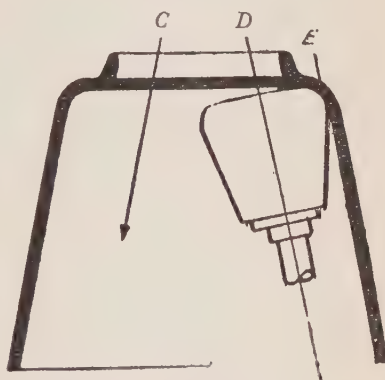


FIG. 26—A KETTLE ARRANGED FOR GRINDING WITH A SO-CALLED POT BALL

At both *A* and *C* it will be noted that the lines, *DD* and *EE*, are parallel representing the sides of the work and the grinding wheel axes.

The general principle followed in hollow-ware grinding is to remove as much metal as possible in one cut. After grinding, a canvas wheel setup with No. 60 abrasive, usually emery, is used to impart a polish. This wheel is substituted for the grinding wheel. A further buffing operation is accomplished with a canvas wheel setup with flour emery. This wheel is used with oil. The lips of skillets are polished with a small conical wheel setup with No. 120 emery. This operation is performed by hand. All that is necessary is to remove the scale. As a rule, aluminum hollow ware is finished entirely by polishing.

INTERNAL GRINDING

Internal grinding includes any phase of grinding that deals with the finishing of bores, holes, etc. Thus cylinder grinding and automotive regrinding are a branch of internal grinding. Such operations are performed on planetary-type grinders. In general internal grinding alludes only to the finishing of work that can be rotated about its axis, which of course is impossible with such parts as six-cylinder engine castings. Internal grinding formerly was performed solely on universal grinding machines, but today, production internal grinding is done on machines which are more rigid and therefore more productive than the universal machine.

One of the most important items pertaining to internal grinding is the wheel itself. The grinding wheel gets its cutting efficiency from its speed of rotation. Thus a wheel that will cut satisfactorily at a peripheral travel of 5000 feet per minute which show low grinding capacity if run at 4000 feet per minute or over speeded and run at 6000 feet per minute. Wheel speed depends upon a number of conditions. In general, moderate wheel spindle speeds and a firmly located spindle will reduce a tendency of small spindles to heat, that is, in cases where the solid bearings are used. With the modern type of spindles, which operate in ball bearings, the factor of heat is automatically taken care of. It must be borne in mind that a soft, free cutting wheel is preferred to a hard one, as the latter will glaze and heat the work unduly. Whether a grinding machine spindle is of the ball bearing or plain type, lubrication is an important factor and it should not be neglected. A special oil provided for the purpose should be used. It can be procured from or recommended by any manufacturer of internal grinding machines. The oil must be of a thin, readily-flowing variety.

Work speed is an important factor to consider in any internal grinding operation. Many operators never change the work speed, they use the same work-head rotation for a two and six-inch hole. This is not good practice. The smaller the hole, the greater should be the work speed and vice versa. The higher the work speed, the harder the wheel must be to prevent breaking down. From this it must not be inferred that abnormal work speed and hard wheels are recommended. A happy

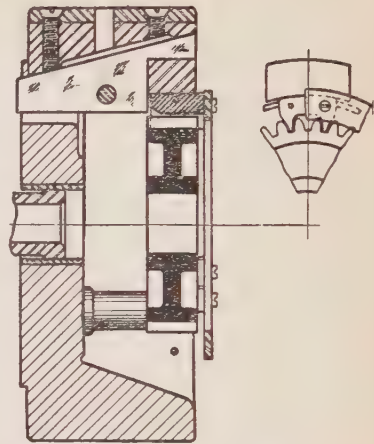
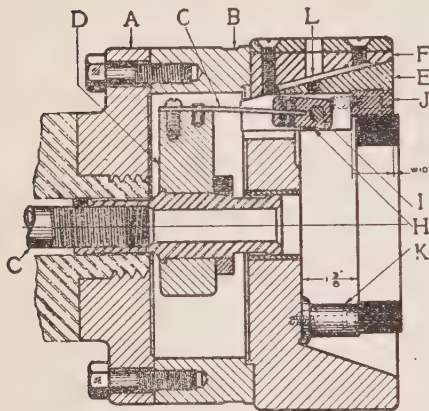
medium should be preserved. Work speeds for internal grinding vary all the way from 10 to 75 feet per minute. As in external grinding, the work speed often must be adjusted to suit local conditions.

The grinding wheel must be kept true at all times. The wheels can be trued with diamond tools, with abrasive blocks or with special mechanical-truing devices, a number of which are on the market at the present time. The operator should never attempt to true the wheel on an internal grinder by hand as it is impossible to do a creditable job in this manner.

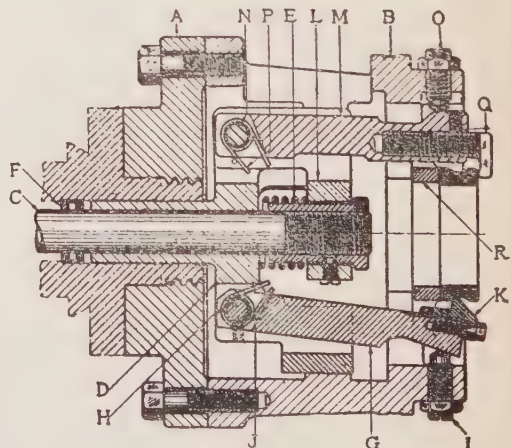
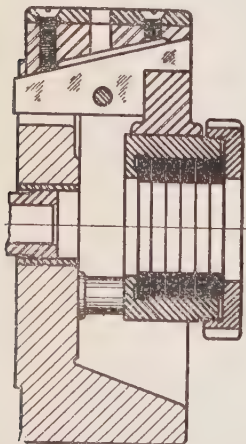
The amount of stock to leave for internal grinding depends on a number of factors, the length of the work in relation to its diameter, kind of material, etc. From 0.008 to 0.010-inch is sufficient for holes up to one inch in diameter and two inches long under ordinary conditions. Larger and longer holes must have a more liberal allowance. Hardened work requires a greater grinding allowance than does soft material. This is because such work distorts in cooling and therefore an allowance must be made to insure the part truing up satisfactorily in the grinding operation.

In general, it is well to leave a liberal allowance, if a rigid machine is available. Light machines cannot remove a large amount of stock economically, thus their field is limited. It is well to check up on the amount of stock to be removed occasionally. Thus let it be assumed that some bushings two inches long are to be ground and that 0.010-inch of stock is left for grinding. The operation should be observed carefully and if it is found that the holes grind out smooth by the time 0.007-inch has been removed it is a sign that the finishing allowance can be reduced. Bear in mind that it costs money to remove stock by internal grinding whereas a few thousandths more can be removed in an automatic screw machine without any cost. On the other hand, if it is found that a number of parts are scrap, due to the fact that they do not grind out, the remedy is to increase the grinding allowance. By checking up on these figures carefully production costs can be reduced materially in a number of instances.

Without doubt one of the most important problems to consider in internal grinding is the manner in which the work is held in the machine. A great many parts are held directly in



the draw-in chucks with which the work head is fitted. When the draw-in chuck can be used, the problem of locating the work is simplified as the operation of the chuck is very rapid and effective. Where draw-in chucks are used it may be a good plan to arrange two machines so that one operator can attend to both. However, it must be borne in mind that this adds an extra-machine-tool cost and if there are not large runs of routine work such a procedure may not always be justified. This is a matter for every production engineer to settle for himself.



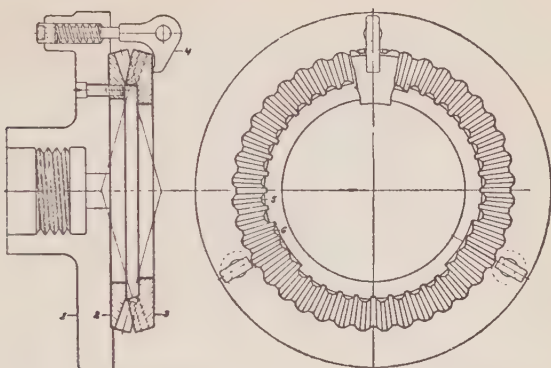


FIG. 31—LOCATING A RING GEAR FOR INTERNAL GRINDING

While the draw-in chuck can be relied on for locating a number of parts quickly and accurately its usefulness is limited. Thus many modifications of the simpler form of chuck have been developed. Such chucks are operated by a rod passing through the work-head spindle, just as the ordinary draw-in chuck is operated. In Fig. 27 is shown the Heald sliding jaw collect chuck which is a semiuniversal unit for holding gears, bushings, rolls, barrels, and like parts. It is loaded from the front and arranged for radial setting and clamping. It locates the work endwise as well as radially.

Referring to Fig. 27, *A* is a standard face plate screwed to the spindle nose. The main fixture body is shown at *B* while *C* is the operating tube. The spacer, *D*, forms the connecting member between the operating mechanism and the jaws. Hardened

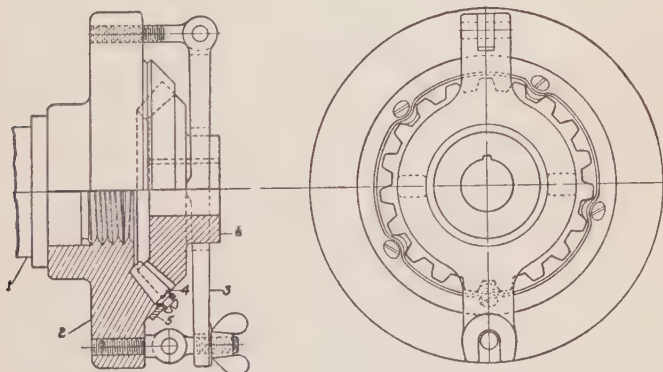


FIG. 32—FIXTURE FOR HOLDING A BEVEL PINION FOR INTERNAL GRINDING

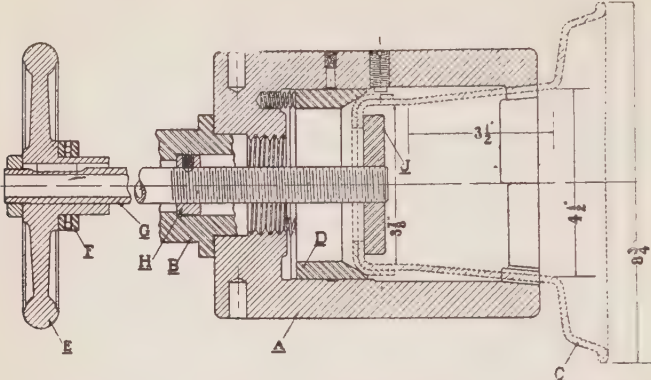


FIG. 33—SIMPLE FIXTURE FOR THE INTERNAL GRINDING OF
PRESSED-STEEL HUBS

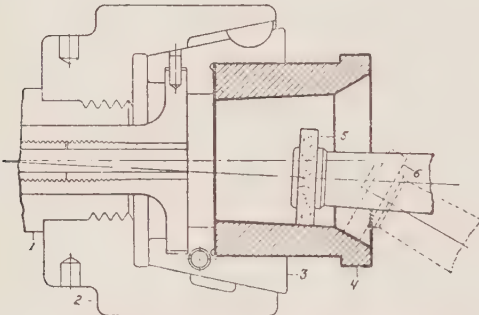


FIG. 34—FINISHING TWO INTERNAL TAPERS
AT ONE SETTING OF THE WORK

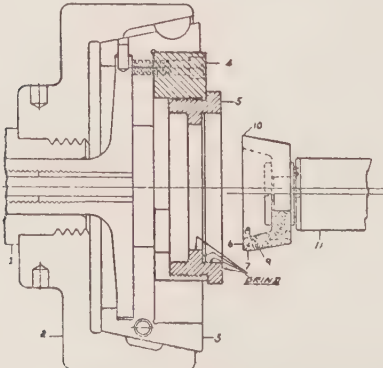


FIG. 35—GRINDING INTERNAL WORK
UP TO A SHOULDER BY USING
A CUP WHEEL

steel angular jaws are shown at *E*, while *G* are flat spring members which form direct connection between the spider and the jaws through the rocker, *H*, and pin, *I*. The inserts, *J*, are interchangeable to suit the work while *K* represents reversible end locating stops. A tapped hole for a binding screw is shown at *L*.

Fig. 28 shows how the chuck is arranged with a rocker cage carrying three 2-point rockers for holding spur gears, locating them from the root diameter. The chuck also can be arranged to locate gears from the pitch-line circle when this is desired. Fig. 29 is an interesting application as it shows how the fixture holds a shuttle, which member carries several pieces to be ground simultaneously. The use of special work-holding fixtures of this kind, wherein a holder can be loaded while the machine is operating with another loaded holder in position, expedites production as it reduced the idle time to a minimum. Another Heald work-holding device is shown in Fig. 30. This is called a finger combination fixture. Its object is to clamp the work through end pressure thus holding it square and preventing distortion. In Fig. 30, *A* is the face plate, *B* the fixture body, *C* the operating mechanism, *D* the centering finger spider, *G* the centering fingers, *H* the pivot on which the finger works, *I* are backing screws, *J* are springs to open the fingers, *K* are finger inserts shaped to meet special requirements if necessary, *L* is the clamping finger spider, *M* clamping fingers, *N* the pivot pin for one of the clamping fingers, *O* and *P* are backing screws and springs, *Q* is a hardened steel clamping finger shoe and *R* a hardened steel clamping plate.

In Fig. 31 is shown a good chuck for holding large bevel gears such as used in automobile rear axle drives. A soft gear, 2, is mounted on the face plate which is recessed slightly to center the master gear to make it run true. The gear to be ground is located with its face to the master gear and held in place with three clamps, 4. Bevel pinions are chucked readily by the method shown in Fig. 32. Taper rolls, 4, are used in this instance. They are uniformly spaced about the gear, 6. The rolls should be three, five or seven in number according to the size of the gear. The method of holding the rolls allows a certain amount of freedom for the purpose of taking care of slight irregularities. The fixture base is shown at 2, the spindle at 1, the clamp at 3, and the roll locating ring at 5.

The device shown in Fig. 33 is a novel arrangement for holding pressed steel hubs for grinding. Such hubs are used on wire automobile wheels. The arrangement embodies a body, *A*, which is screwed to the spindle nose, *B*, of the grinding machine. The work is represented at *C*. *D* is a compensating seat against which the work bears. It is pushed forward by a number of coil springs, one of which is shown. The hand wheel for setting the work in place is shown at *E*, while *F* is a ball thrust to take end play. *G* is the handwheel spindle and *H* a centering collar.

The grinding of two tapers at one setting is shown in Fig. 34. This is accomplished by setting over the grinder headstock which is provided with graduations for this purpose. In grinding a number of pieces on a commercial basis it is well to grind one angle on all the pieces before setting up for the other angle. In the illustration 1 is the spindle, 2 the fixture base, 3 the work seat, 4 the work and 5 and 6 the wheel positions.

Work can be ground up to shoulders and the shoulders finished also by using the method shown in Fig. 35. A cup wheel is used as the illustration shows. In the illustration, 1 is the spindle, 2 the fixture base, 3 the clamping device, 4 the work seat, 5 the work, 6, 7, 8, 9 the wheel cutting surfaces, 10 the wheel and 11 the wheel spindle. By truing off the outer diameter of the wheel slightly with a diamond tool, at 7, the wheel will be in condition for grinding the holes, while the surface, 6, will finish shoulders. As the wheel wears away, the same surfaces can be maintained as at 8 and 9 and the wheel used until worn out.

Magnetic chucks also make excellent work-holding devices. In grinding holes in rollers such as are used in automobile engine tappets, these rollers are first faced accurately on the sides. Then by locating them on a magnetic face-plate fixture the hole is ground rapidly and accurately. As the locating time is very slight, it is seen that one man can operate one machine, keeping it at maximum production. The subject of locating fixtures without a magnetic chuck for grinding is an interesting one and one that promises great developments in the future. Often it is advantageous to locate the work directly in the work head of the grinding machine in a special fixture. In a typical operation the work consists of the internal grinding of an airplane engine cylinder. In this operation, the cylinder casting is located di-

rectly in a fixture in the work head. A number of large and bulky pieces can be ground satisfactorily in this manner.

Where it is necessary to finish two holes in one piece at one setting such as holes in pistons for wrist pins or two holes of different diameters in cluster gears for automobile transmissions, the double-spindle internal grinding machine is a valuable tool to consider. This machine locates the work in a work head which is centrally located on the machine bed. Two grinding heads are provided so that both holes can be worked upon simultaneously. A machine of this kind of course is more or less of a special tool, but where long runs of repetition work are to be had it will prove a valuable asset in cutting down production cost as two

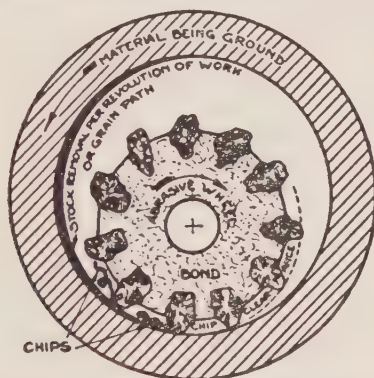


FIG. 36—PRACTICAL ILLUSTRATION OF THE CHIP CLEARANCE

holes are finished in one setting and thus the grinding time is reduced approximately 50 per cent.

Chip clearance is an important factor to consider in internal grinding, according to R. L. Morgan. Too heavy a cut either loads the wheel or breaks it down, causing the cutting tools to be destroyed by tearing them away from the bonding material. Therefore, a limiting factor in connection with internal grinding presents itself. The depth of cut should be determined by the chip clearance which is illustrated in Fig. 36. In light of present knowledge, this limiting factor cannot be overcome. Therefore, the width of the wheel face has been increased from 100 to 200 per cent. Such a wheel presents an increased number of cutting tools to the surface being ground. The next step is to feed more workable surface to the added number of cutting tools. This involves an increased traverse. The movement often is

actuated by a simple hydraulic mechanism which gives a range of table speeds up to 50 feet per minute.

This practice permits the use of broadface wheels, the entire surfaces of which are utilized for grinding instead of edge or corner cutting only. The entire cutting surface of the broad-face wheel is presented to a new surface upon the part being ground at each revolution. In other words, a spiral is ground allowing the wheel to overlap its path of advance just sufficiently to cover and eliminate feed lines, as shown in Fig. 37, thus making use of almost the entire cutting face of the wheel. Such a

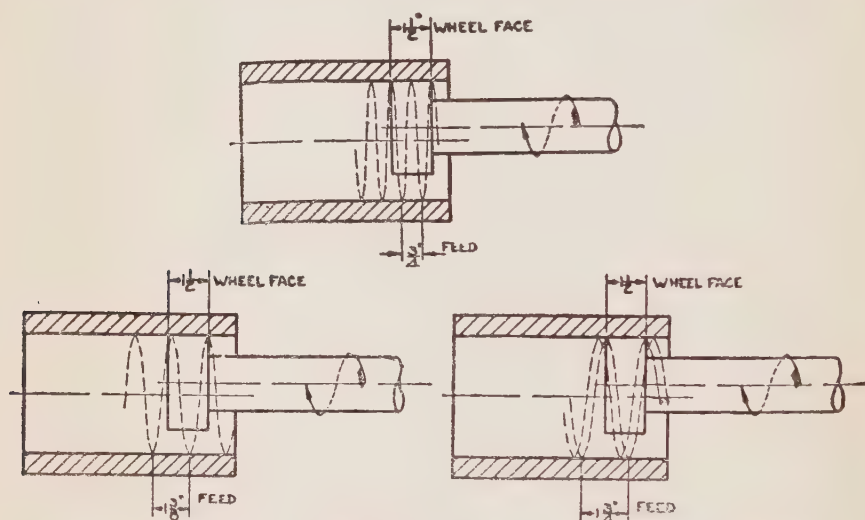


FIG. 37—GETTING THE BENEFIT OF A WIDE-FACE WHEEL IN INTERNAL GRINDING PRACTICE

procedure gives greatly advanced production, together with marked economy of wheel wear because the entire wheel face is engaged in cutting. The chart in Fig. 38 gives table traverse, wheel widths and revolutions of the work as applied to everyday production grinding operations.

For example, let it be assumed that a wheel face of $1\frac{1}{2}$ inches and a work speed of 350 revolutions per minute are employed. What should the table traverse be to permit of utilizing the entire face of the abrasive wheel? At the bottom of the chart is noted a work speed of 350 revolutions per minute. The table speed in feet per minute is given at the intersection of this vertical line with the diagonal $1\frac{1}{2}$ -inch wheel face line. This

GRINDING PRACTICE

point of intersection indicates a table speed of almost 43 feet per minute. On the other hand, let it be assumed that the table traverse is set at 32 feet per minute and the work speed has been found to be 425 revolutions per minute. What face wheel should be used? Following the horizontal line from 32 feet table speed to the right until it intersects the vertical line projected

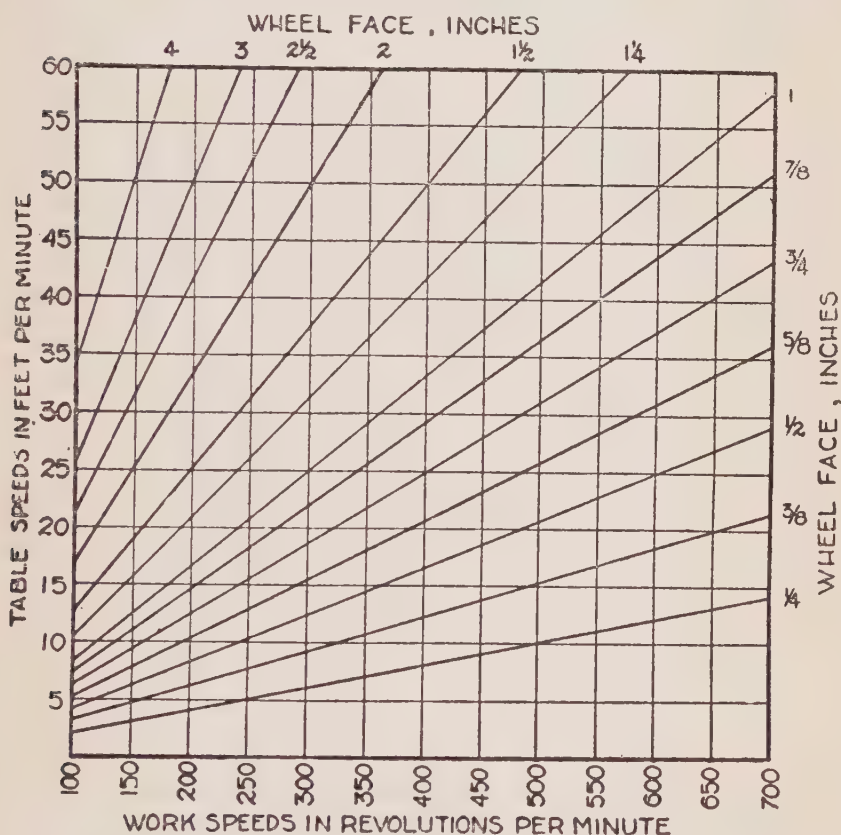


FIG. 38—DATA FOR INTERNAL GRINDING PRODUCTION OPERATIONS

above the 425 feet table speed, it will be found that a $\frac{7}{8}$ -inch face wheel will be ample to do this work.

If we have a wheel face of $\frac{3}{4}$ -inch and a table traverse of 25 feet per minute at what speed should the work head be revolved? In the vertical column at the left of the chart follow to the right the horizontal line indicating a table speed of 25 feet per minute, until it cuts the $\frac{3}{4}$ -inch wheel face, diagonal

line; then drop to the work-speed line and it will be noted that the revolutions per minute of the work should be 400. The foregoing examples show the practical use of the chart in everyday grinding practice.

During the past few years great strides have been made in the introduction of automatic internal grinding machines. These grinders reduce production costs materially as they eliminate the human factor to a great extent. These machines are equipped

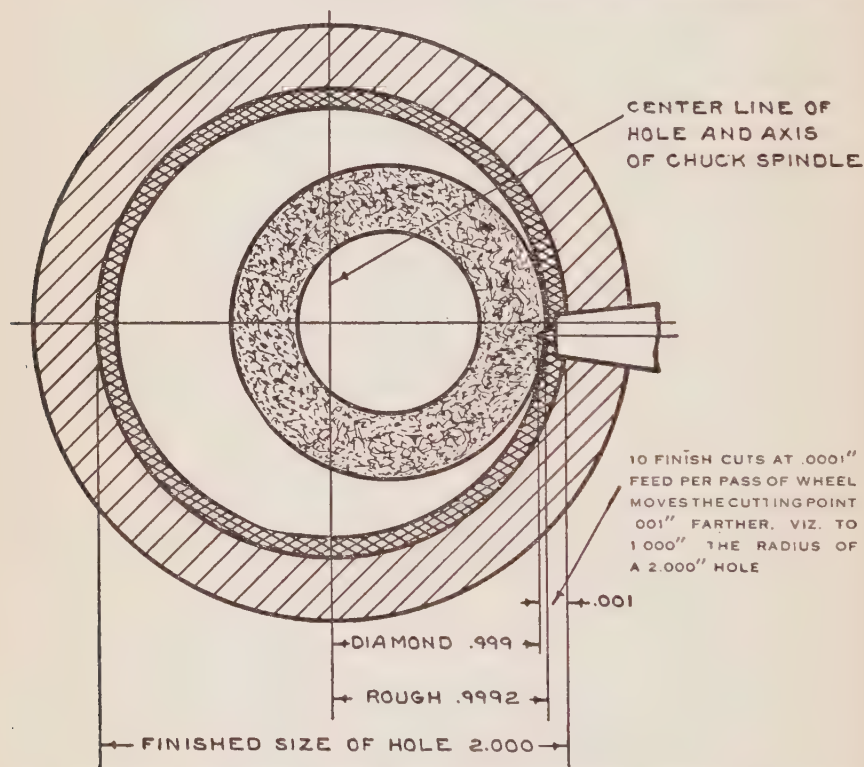


FIG. 39—METHOD OF SIZING WORK ON A SEMIAUTOMATIC INTERNAL GRINDING MACHINE

to rough grind the hole to a predetermined diameter. Then the wheel is trued automatically and the finishing cut taken. The device which controls the movements of all the units after the operator has chucked the work and started the machine is a simple and automatic arrangement with a diamond-pointed finger that is in contact with the hole of the work at all times when grinding.

The method of sizing the work on the Heald internal grinder is explained diagrammatically in Fig. 39. Suppose the hole to be finished is 2.000-inch diameter the wheel is allowed to rough out the stock until 0.0008 inch is left on the side so that the hole when the wheel withdraws from the work to be trued measures 0.9992 inch from the center. The diamond has been set 0.999 inch from the center allowing 0.0002 inch to be trued off or just enough to clean the wheel. The wheel now starts to grind at a finishing speed and finishing feed of 0.0001 inch per pass with the result that on ten passes of 0.0001 inch gives the 0.001 inch desired, making the hole exactly 2.000 inch.

In other words, having roughed the hole to nearly finish size, the diamond is set to true the wheel at this point, then by knowing the amount of stock being removed per pass of the wheel, it is a simple matter to advance the cross slide a definite amount to secure exactly the same size hole on each successive piece. There is, however, another factor to be considered and that is the wear of the wheel due to the grinding action and truing. To compensate for this wear, each time the table comes to rest position, there is an arrangement on the cross slide that advances it sufficiently to allow a slight amount of material to be dressed off the wheel each time it is presented to the diamond. In removing this last amount of stock, the operation is accomplished under ideal conditions for the wheel has just been trued, presenting a clean, sharp surface to a definite amount of stock to be removed. The feed is fine, the speed is correct therefore under these conditions, the result is exact duplication as long as the relationship of the point of truing and the finish size remain the same.

Automatic internal grinding is in its infancy at the present time, but remarkable progress certainly has been made in its introduction and before long the automatic machine probably will be introduced generally in automobile and other plants where intensive production operation are paramount. The operation of an automatic internal grinding machine differs in no way from that of an ordinary internal grinder in principle. That is, the work is chucked and ground in the same way; the automatic features, of course, reduce production cost materially, for once the work is set up and the size determined on the machine will continue to grind and finish to this size until it is necessary to replace the grinding wheel.

In automatic internal grinding wherever it is possible the work should be located in a shuttle so that the loaded member can be set in the machine rapidly and quickly. Thus the operator can load one fixture while another is in process of grinding. It must be borne in mind that every second a grinding machine is stopped means idle time, therefore, if means can be introduced to keep a machine running continually, that is by loading one fixture while another is in process of grinding, the idle time is cut down to a minimum and this spells production.

JIG-BUTTON GRINDING

As a rule, jig buttons can be purchased from outside sources cheaper than they can be made in the average shop. However, it often is necessary to provide special sizes and to avoid delay they can be made readily by any toolmaker. Operations preliminary to grinding consist of drilling and reaming the hole and locating the work on an arbor where the ends are faced and the outside diameter turned leaving about 0.01-inch for finishing by grinding. Next the button is located in a chuck and one end recessed to leave a bearing at the outside only, say 1/16-inch. After hardening the button is mounted on an arbor between centers on a cylindrical grinding machine. It is important to grind the periphery and to finish the bottom at one setting on the arbor. In this way the correct relation between these two surfaces is assured. The bottom of the button is ground on the side of the wheel, which should be recessed slightly to assure a smooth cut. The periphery of the button is ground in the usual way, exercising care to finish it to the exact size desired. The wheel to use for this work should be comparatively soft and free cutting.

KEYWAY GRINDING

Sometimes keyways are ground in shafts, generally because someone neglected to cut the keyway before the part was hardened. If the shaft is manganese steel, the keyseating always must be done with a grinding wheel. The shaft can be located on the platen of a surface grinding machine and the wheel set central. In general, elastic-bond wheels in an alumina abrasive should be used. The feed should be slow, about ten feet per minute, and the wheel fed down a little at a time until the desired depth is reached. Internal keyways are ground by a special appliance

consisting of a small alumina abrasive held on the end of a square shaft. This is slow work as the depth of cut cannot be deep. Generally special machines are used for the purpose. One type consists of a ram for actuating the wheel holder while the work is located on an angle iron.

KNIFE GRINDING

Failure to obtain satisfactory results in machine knife grinding, according to Theo. Giles and Charles A. Runo, is due to some failure in the method employed. The direct cause of much of the trouble experienced is excessive heat generated in grinding. This tends to draw the temper and burn the edges, causing checking or cracking, and sometimes warping or "bowing" of the knives. The more common causes of excessive heat are as follows:

- 1—Grinding wheel (too hard or too fine).
- 2—Dressing method.
- 3—Wheel speed.
- 4—Rate of feed and speed of traverse.
- 5—Coolant or lubricant.

In selecting the grit and grade of wheel for grinding knives, it is well to consider first a few of the fundamental rules which apply to knife grinding. The broader the contact (width of bevel) the softer the wheel should be. On very broad work, special abrasives are desirable because of the cooler cutting action. Hard steels require soft wheels. A wheel which is satisfactory on hard steel can usually be made to produce satisfactory work on soft steel also, but it may not be the most economical. The reverse is not always true, because a wheel which is satisfactory on soft steel may be entirely too hard for hard steel.

In general, high speed steel usually requires a softer wheel than carbon steel, and special abrasives are often most efficient on this material.

On the other hand, some of the carbon steel knives, such as veneer and slicer knives, have a very wide bevel, sometimes necessitating the use of soft wheels. In some instances, coarser wheels will usually permit deeper cuts than can be taken with finer ones, but the resultant finish will not be as fine. It is possible, however, to produce a good finish with a coarse wheel if the face is first accurately trued with a diamond. Where sev-

eral kinds of knives are to be ground with one kind of wheel it is well to lean toward softer wheels. However, if a considerable proportion of the knives to be ground are of softer steel or have narrow bevels, it will be more economical to use two different wheels.

The range of grains and grades adapted to this class of grinding is small, and it does not require much experimenting to find the best wheel for a given job. A wheel of a grain and grade which has proven satisfactory on similar work should be chosen for first trial. A short test should indicate if it is desirable to make any change. If a change is necessary, it will only be necessary, in most cases, to go one grade softer or harder or one grain size finer or coarser. Veneer, slicer, and paper knives require a straight or nearly straight bevel and are therefore best ground with cup wheels. For veneer and slicer knives where the bevel is very wide, a 36 grit silicate wheel in an alumina abrasive is recommended for the first trial.

On hog, chipper, barker and planer knives a concaved bevel is permissible and they may therefore be ground with either straight or cup wheels. The best first choice for knives in this class would be a 36-grit alumina wheel. If 30 inches or larger in diameter, the wheels should be made by the silicate process. If smaller than 30 inches in diameter, they can be made in either silicate or vitrified process. Any attempt to increase wheel life by using wheels finer or harder than they should be, will usually be unsuccessful because the wheels will be apt to glaze quickly, cause excessive heat and danger of spoiled work, and necessitate frequent dressing. Also by using a wheel coarser or softer than necessary, in an attempt to speed up production. excessive and uneven wear is apt to result.

The method of dressing the grinding wheel is often of greater importance than is at first imagined. The object of dressing the wheel is to produce a free-cutting surface on the wheel after it has become glazed and to make the grinding surface run as nearly true as possible. The most satisfactory method of truing or dressing the wheel is by the use of a diamond tool, securely fastened to the work table of the machine, so that it can be traversed across the wheel face in a true plane. By this method the wheel can be made more nearly true than by other methods. By varying the depth of cut and speed of traverse of the diamond, it is possible to vary the texture of the

grinding face. The slower the traverse and the lighter the cut, the smoother the wheel face will be and consequently the finer will be the finish on the knife. With the wheel face in this condition, however, the wheel will act harder and glaze more quickly. Conversely, by using a faster traverse and a heavier cut, the wheel face can be opened up or roughened causing it to cut more freely and with less heat, but with a resultant coarser finish on the work.

Perhaps the most common method of dressing the wheel is by the use of an abrasive brick supported on the work table and guided by hand. This method requires skill to make the

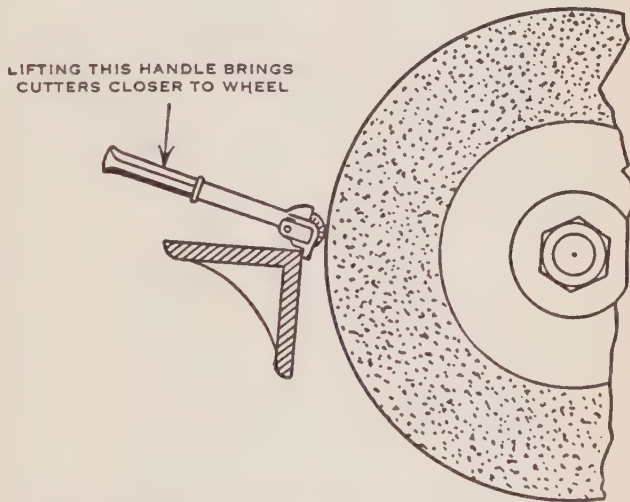


FIG. 40—TRUING A WHEEL WITH A HUNTINGTON-TYPE DRESSER

wheel run true, as it is difficult to hold the brick rigidly. The brick also frequently produces a smooth or glazed face on the wheel, instead of opening it. Sometimes the entire surface is glazed causing the wheel to act hard and burn the work. At other times, due to the wheel being out of true, the glazing will be on spots only, resulting in so-called hard and soft spots.

In many mills where unsatisfactory results were being obtained by the use of bricks, these have been satisfactorily replaced with huntington type dressers. Such a dresser, as shown in Fig. 40, consists essentially of a number of steel disks with saw-tooth edges, which revolve freely on a spindle secured to a

holder or handle. The lower part of the holder has two square projections which should be hooked over the edge of the table. This enables the operator to slide the dresser across the wheel more smoothly and minimizes the tendency to follow any irregularities in the face of the wheel. The edge of the table serves as a fulcrum and by raising or lowering the handle, the depth of cut can be controlled at will. When a huntington dresser is used properly, it is possible to produce a shape which is more nearly true than can be obtained by the use of a brick. The surface produced is usually more satisfactory as it is more open and free cutting.

The speed of the grinding wheel is important as this has an influence on both the rate of production and the quality of work. Up to the certain point, an increase in the wheel speed will also increase the speed of production. Beyond this point, however, the increased speed will make the wheel act hard, so that burned work is apt to result. Excessive speed is also apt to cause vibration of the machine and may introduce the danger of wheel breakage. The general tendency is to run the grinding wheels too slow and very few instances are found where excessive speeds are used. In fact many operators would materially improve their present production if they increased the speed of their grinding wheels.

The surface speed of cup wheels should be between 3500 and 4500 surface feet per minute. Straight side wheels can usually be run somewhat faster. Thin high-speed steel knives are usually ground with a speed between 4000 and 5000 surface feet per minute. The higher wheel speed seems to do the work much better and with less heat than when lower speeds are used.

Where straight side wheels are used, it is advisable to increase the spindle speed as the wheel wears down to keep the surface speed nearly constant. This is not necessary with cup wheels, because the diameter is not reduced by wear and the surface speed of the rim remains the same, throughout the life of the wheel. If lower speeds than those recommended are used, the grinding action is apt to be erratic and the wheel is apt to wear unevenly and excessively.

Many knives have been ruined by attempting to hurry the grinding. This is especially true when, because of nicks, cracks or other defects, it is necessary to remove a large amount of

material. There is then a great temptation to use a deep feed or fast table traverse or both, in an effort to remove a maximum amount of material in the shortest time. It should always be remembered that there is a limit to the cutting capacity of every grinding wheel of any grain and grade. It is a general rule that softer wheels allow of deeper feed than finer and harder ones. To force any wheel beyond its capacity, however, will result disastrously, because excessive heat will surely be generated.

No definite rules can be laid down for the exact amount of feed or speed of traverse, as these factors are influenced by other conditions. The exact rates must be determined by experiment for each case. As a general rule, however, it will be found that it is more economical to use a relatively light cut and fairly fast traverse than to use a very deep cut with slow traverse. To produce a fine edge it is advisable to make the two or three final passes with a very light feed and a slow traverse.

The question of whether the grinding of knives is done better wet or dry is much debated. It is not the intention to attempt to settle this question one way or another, because both methods have their merits. We believe it is generally agreed, however, that wet grinding to be successful, must make use of a large amount of water or lubricant. The importance of this cannot be overemphasized. Most machines are equipped with water attachments, but some of these do not provide sufficient quantities. As one practical man puts it: "The water must prevent the knife from getting hot and not cool it after it is hot." In order to do this a large stream of water must be provided and this should be directed at the point where the heat is being generated, namely, at point of contact between wheel and work. A small amount of water allows the knife to heat up and then cools it after it leaves the wheel. This is the direct cause of much of the trouble experienced.

When grinding is performed wet, it is usually better to use a grinding lubricant, rather than clear water. There are a number of commercial compounds on the market, sold under various trade names which will make satisfactory lubricants. If it is desired to prepare a satisfactory "home-made" lubricant, this can be done by adding one gallon of lard oil and five pounds of sodium carbonate to 40 gallons of water. Such a lubricant has a tendency to reduce the amount of power required and also prevents the machine and knives from rusting.

Thin high-speed-steel knives can be successfully ground without the use of water or lubricant, if the proper grain and grade of wheel, wheel speed, correct feed and speed of traverse are used. As pointed out previously, it is better to grind this way, unless a copious amount of water is available. Many experts claim that it is much better to always grind this type of knives dry. Hardened and tempered carbon steel knives must be ground wet in order to obtain satisfactory results. If these knives are ground dry the temper is apt to be destroyed.

An ingenious method of overcoming, to a certain extent, the inadequate supply of water furnished by some machines, has been used by some operators and is shown in Fig. 41. The

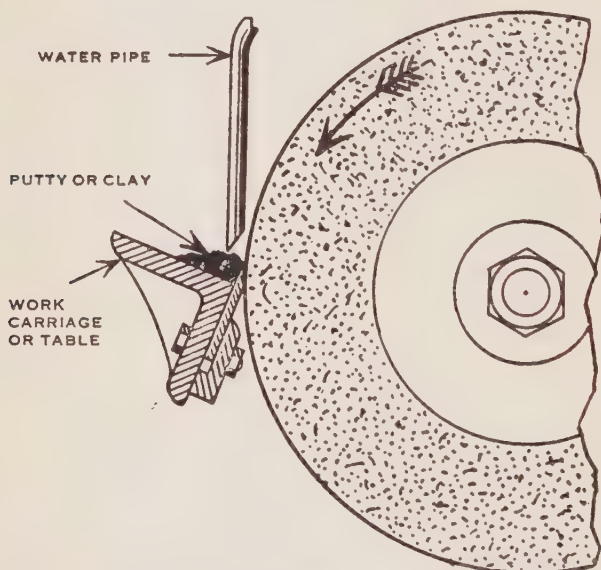


FIG. 41—THE WHEEL ROTATES AGAINST THE CUTTING EDGE OF THE KNIFE

knife is clamped to the table so that it projects above the table about $\frac{3}{4}$ of an inch. By damming the end with putty or clay, a reservoir will be formed between the knife and the tilted carriage. This will fill with water which will keep the knife cooler than a small stream or trickle running over only one place.

The more rigid the machine, the better will be the quality of the work produced. It should be set on a good solid foundation to minimize vibration. Vibration causes excessive wheel wear and makes it difficult to produce high grade work. Most

operators agree that grinding against the cutting edge shown in Fig. 41 gives better results than grinding in the opposite direction. Grinding against the edge produces a better edge and some operators claim that the edge is not heated as much.

It is important to have the knives properly clamped to the carriage in order to prevent warping or "bowing." Some experts suggest grinding the knife to an edge and then letting it rest until it is perfectly cool before making the final finishing cuts. These finishing cuts should be very light and are intended to remove any high spots which might exist, thereby insuring a straight edge. It may not be necessary to follow this practice to secure good results, but the method described certainly cannot be the cause of defective work and might be well worth a trial, in case satisfactory results are not being obtained by other methods.

Although jointing is an entirely separate operation from grinding, the two are somewhat related. Jointing, if carefully and properly done, will prolong the period between grinding. On the other hand, if the grinding is not carefully done, the jointing operation will be difficult, and the results will not be satisfactory. The selection of the grade of stone for this work is of importance. It should not be too fine or too hard or it will burn the edges of the knives. If too coarse or too soft, it will wear away quickly and will not produce a satisfactory edge. A coarse jointer stone will prove to be satisfactory in most cases. The medium or fine stones are usually too dense. These stones are manufactured alumina.

LAWN-MOWER SHARPENING

Lawn-mower reels are sharpened as a production operation on regular cylindrical grinding machines. The work is dogged in the usual way and driven between centers. Generally a comparatively hard wheel is used as the action of the blades passing the wheel act as a dresser. This operation is performed wet. Grinding of the lower or straight knife is essentially a surface or knife grinding operation. It usually is performed by locating the knife and its knife bar in a special machine where it is fed past the face of a cup wheel.

Lawn mower sharpening as repair work is performed by locating the reel between centers and backing it off just as a spiral milling cutter is ground. Usually special machines are used for

this purpose. The lower knife is sharpened by holding it in a special holder and feeding it past the wheel. Usually an alumina wheel in 36 to 46 grit and medium grade is used. Generally this work is performed wet.

MEAT-CUTTER KNIFE GRINDING

Meat-cutting knives of the type involving a perforated disk can be ground readily on almost any type of equipment where flat surfaces can be generated. Disk grinding machines will answer the purpose. The side of a grinding wheel can be used if it is flat. Rotary platen surface grinders are excellent for this purpose. The knife should be ground perfectly flat and just enough stock removed to sharpen it.

PIPE-BALL GRINDING

Pipe balls are used for forming the inside diameter of tubing. They are manganese steel generally and vary in sizes up to six inches. They are shaped something like a projectile, but with a short body. The body part must be ground accurately as it determines the tube size. Centerless grinding machines have been employed for finishing these parts with good results. Balls up to $4\frac{1}{4}$ inches in diameter are finished by centerless grinding by a prominent Mid-Western manufacturer of manganese steel. Larger sizes are ground on cylindrical grinding machines. Usually special fixtures are necessary for locating the work. In the centerless grinding operation about $\frac{1}{8}$ -inch is removed in 12 passes. Limits of accuracy are plus or minus 0.005-inch. A 16-inch pipe ball weighs about 400 pounds. Approximately $\frac{1}{4}$ -inch is removed in the grinding operations. Wheels for this work are manufactured corundum about 24 combination grit and medium grade.

PISTON GRINDING

The majority of automobile pistons are finished by grinding, although one or two manufacturers favor the rolling process, possibly because it is cheap. Pistons can be ground by locating the head against the tailstock center of an ordinary cylindrical grinder, while the other end of the piston fits a special combination center and driver. Another method is to use a special piston-grinding machine which holds the work against a driving fixture by means of a draw-in rod with a hole at one end

through which a short bar is passed. This bar locates in the wrist-pin hole in the piston. Piston grinding does not differ materially from any cylindrical grinding operation. The piston skirt generally is finished larger in diameter than the head portion so that two cuts are necessary. Pistons can be ground by traversing them or feeding them to the wheel without traversing. In general, it can be stated that the former method is preferred. Pistons also have been ground satisfactorily on centerless grinding machines. Carbide of silicon wheels are used for grinding both cast iron and aluminum alloy pistons. The amount of clearance to leave varies greatly among different manufacturers but in general an allowance of 0.001-inch undersize for every inch of cylinder diameter is satisfactory.

PISTON-PIN GRINDING

Piston pins, or wrist pins as they sometimes are termed, can be ground between centers on an ordinary cylindrical grinding machine. As the pin is tubular it is a simple matter to locate it on a work arbor of special design. Such an arbor carries a taper seat at one end and a taper face nut at the other end. By setting up the nut, the pin is held securely by taper seats formed in each end for the purpose. This method is comparatively slow as it is necessary to locate each piece individually. However, the operator can load one arbor while a pin is in the process of grinding which reduces the production time somewhat.

Without a doubt, better results are obtained by using a centerless type machine. All that is necessary for the operator to do is to keep the feed chute full from which place they are conveyed to the grinding station by gravity. Usually about 0.015-inch is allowed for grinding, the pins being passed through the machine several times. Vitrified wheels are used for rough-grinding, but better results are obtained in finishing through the employment of rubber or shellac wheels.

Due to the extreme accuracy insisted on by automobile manufacturers, it is customary to finish the parts in question with extreme accuracy. For this reason piston pins often are subjected to a lapping operation on a special machine before they are passed to the inspection department. Such accuracy is unwarranted, however, since the accurately ground pin often works in a hole reamed in cast iron. If it is necessary to hold the pin

to within 0.00005-inch of tolerance, the hole that it fits also should be finished accurately and smoothly by grinding.

PISTON-PIN HOLE GRINDING

It is not common practice to grind the holes in pistons that accommodate the piston pin, but this procedure is logical since automobile manufacturers insist on high accuracy in piston pin dimensions. For this reason the hole that the pin fits also should be smooth and accurate. A few machines are on the market for finishing piston pin holes by grinding and their use probably will be furthered during the next few years. The means employed are to locate the piston in a revolving work head and to grind the holes with two wheels working one in each hole simultaneously.

PISTON-RING GRINDING

Piston rings are ground on their sides so that they will fit the grooves in the piston accurately. If they fit loose, a clicking sound is emitted which is not to be desired. Ordinarily the rings are located one at a time on a rotary-chuck surface grinding machine. Better results are had from a production point of view at least by utilizing a semiautomatic piston-ring grinder. Such a machine is fitted with a feed chute which feeds in one ring to the grinding position at a time. The sides of piston rings are often rough ground on a double-disk grinder. Such machines also are automatic in operation, so that all the operator has to do is to keep the feed chute full.

The peripheries of piston rings are ground, in some instances, but latter-day practice seems to favor the turned ring. The argument in favor of the turned ring is that the turning operation shows up any hard spots that might wear the cylinder wall unduly. When the ring peripheries are ground, however, it is common practice to locate a number of them in an ordinary cylindrical grinder special arbor by means of a locating fixture devised for the purpose. It can be said of the ground rings that they present smooth surfaces which wear in very readily.

PISTON-PIN HOLE RELIEF GRINDING

It is considered good practice to relieve the metal adjacent to piston pin holes in automotive practice. Some manufacturers cut a relief band encircling the entire piston. This can be done on the lathe but it reduces the wearing surface. A better plan

is to grind a slight relief at each hole. The piston is located between centers in a plain grinding machine and a plug carrying a handle about two feet long is inserted in one of the piston pin holes. The handle is arranged to work between two stops which limit the amount of travel, and consequently the relief cut. With the work located, the operator brings it up to the wheel feeding it in a predetermined amount, then the handle is moved downward which causes the wheel to cut the desired path. The piston then is turned 180 degrees and the hole on the other side relieved. More economical results can be obtained, however, by using a special piston-grinding machine designed to finish the outer diameter and grind the relief at the piston-pin holes at one setting of the work. In operating a machine of this type, the cylindrical part of the piston is finished; then the reliefs are ground. The mechanism for actuating the movement for this operation is driven through a cam motion.

PLOW GRINDING

Plows are of two kinds, chilled iron and steel. Chilled plows are preferred for cultivating sandy ground as they withstand the abrasive action of the soil to a remarkable degree. On the other hand, a chilled iron plow will not *scour* or free itself of soil accumulations as well as a steel plow does in loamy soils. In plowing very rich loams, it is almost impossible to use a chilled plow. Some plow manufacturers confine their output to either chilled or steel plows, while others make both kinds.

Abrasives play a very important part in plow manufacture for without their use it would be impossible to market a satisfactory product. Many years ago grindstones were used for finishing plows, but they have been substituted by abrasive wheels. The latter are faster cutting and cleaner in operation. Abrasive practices differ in representative plants. In general, however, the various parts are fitted together by grinding their edges, the assembly then being surface ground and polished. At the plant of the Oliver Chilled Plow Works, with a capacity of 800,000 plows annually, the abrasive processes are as follows:

The first grinding operation consists of fitting the various parts to templates by grinding their edges. These parts are called the point, that part that breaks the soil; the mold board, the part that turns over the furrow; the landslide, the straight part back

of the mold board, and the frog. The latter member holds the others together, but it is not ground. In fitting the parts to the templates, the edges are ground by hand on a floor grinding stand.

The parts then are assembled to form the plow base. The next grinding operation consists of grinding the entire surface of the base. The plow base is located on a cradle with two handles so that the operator can pass it back and forth under the wheel. These wheels are about 30 inches in diameter and 4-inch face and they are mounted on a large machine called a *plow grinder*. At the Oliver plant, this operation is performed wet, although this practice is not universal. Carbide of silicon wheels are used both for fitting and surfacing.

The final abrasive operation consists of polishing. This is performed under canvas wheels setup with aluminum oxide abrasive grain in grits running from 24 to 36. After polishing, the parts are given a coat of varnish to exclude moisture so that the surfaces will not be subjected to rust during transportation.

In the manufacture of steel plows the various parts are purchased in so-called *plow shapes* from steel manufacturers. These parts are heated and forged to shape under heavy dies. They then are ground on the edges and the units fitted to form the plow base. As a rule but little grinding, aside from fitting, is followed in the manufacture of steel plows. After the base is assembled the bolt heads are ground down flush and the base polished on a canvas wheel setup with aluminum oxide grain.

An important branch of plow manufacture consists of furnishing repair parts. These must be fitted accurately to templates and then surface ground and polished. The necessary bolts are set in place before surfacing, a block of wood with a hole being used as a filler piece so that the nut can be set up tight. With the bolts in this position it is an easy matter to grind their heads down so that they will set flush with the finished surface.

PLOW-POINT GRINDING

This is essentially a rural industry and consists of sharpening the forward part of a plow technically called the *point*. These points become dull through the abrasive action of the soil so that it is necessary to sharpen them at least once every season. Chilled-iron points are ground on carbide of silicon wheels. Steel plow points generally are heated and drawn out to a sharp edge

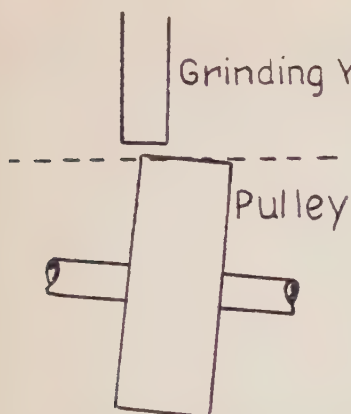


FIG. 42—CROWNING A CAST IRON PULLEY BY THE DOUBLE-CUT METHOD

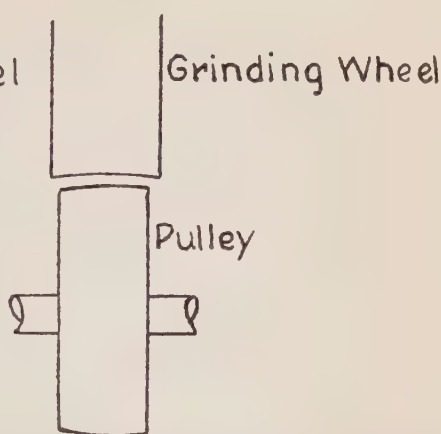


FIG. 43—THE WHEEL FACE IS FORMED CONCAVE TO GENERATE THE CROWN

on the anvil. Nearly every cross-roads blacksmith shop is equipped with a wheel for plow grinding and in the spring of the year it is not uncommon for a blacksmith to grind 40 to 50 points a day at a charge of approximately 30 cents each. Many blacksmiths make the mistake of using a wheel too hard for this work. A wheel for plow point-grinding should be one grade softer than a wheel used for snagging gray iron castings. Thus as a carborundum wheel is 20 grit, *G* plus grade is satisfactory for snagging castings, the same wheel for plow point grinding should be 20 grit, *H* plus grade. The latter wheel cuts the faster and thus enables the operator to grind more points in a given time.

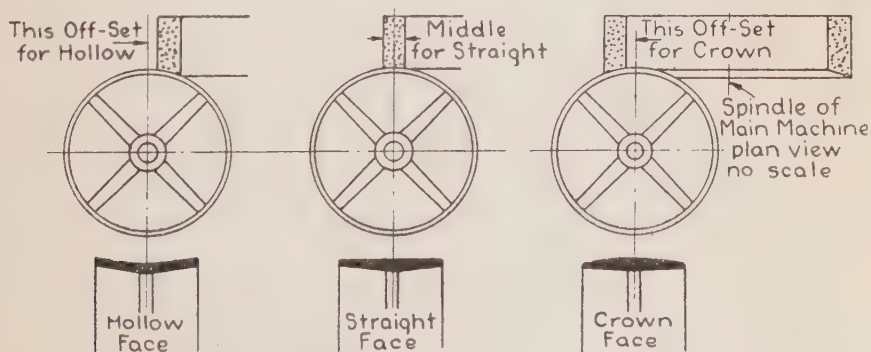


FIG. 44—THREE TYPES OF PULLEY CROWNS CAN BE GENERATED BY THIS METHOD

PULLEY GRINDING

Pulley faces can be finished economically by grinding them from rough castings. A simple method consists of mounting the pulley on an arbor which is located between centers on an ordinary cylindrical grinding machine. The table of the machine is set at an angle for generating the necessary crown as shown in Fig. 42. It is necessary, to make two cuts to crown each side of the pulley, the work being reversed end for end after taking the first cut. In the illustration it is obvious that the wheel will grind along the dotted line. Pulleys also are ground by forming the wheel face as shown in Fig. 43. A special radius truing device must be used to generate the concavity on the wheel face. The wheel should be slightly wider than the pulley face. In this operation the work is fed directly to the wheel without traversing.

Several special pulley grinding machines have been devised. One introduced by the Diamond Machine Co. employs a cylinder wheel operating on the principle shown herewith. Located as shown at the left in Fig. 44, a hollow-face pulley would be ground. Positioned as shown at the center a straight face would be generated. At the right a crown is ground. It is obvious that by changing the relation between the wheel and the work, any desired face from a hollow to a crowned one can be had. The grinding wheel of this machine is a cylinder mounted on a horizontal spindle, while the work is located on a vertical spindle. The work is rotated by a small *burr*, driven by power. Carbide of silicon wheels in comparatively coarse grits should be used for grinding cast iron pulleys. Wood or composition pulleys are not finished by grinding, although there seems to be no good reason why such an operation would not be practicable.

RAILROAD SHOP GRINDING

Abrasive processes are used extensively in railroad shops to replace operation heretofore performed by milling, planing and turning. A diversity of cylindrical work such as piston rods, locomotive and car axles, crankpins, studs, etc., are rough turned and finished by grinding. For many years the opinion persisted among railroad shop master mechanics that grinding wheels loaded the surface finished with abrasive, but in the light of latter-day knowledge this theory has been dispelled.

Piston rods that have been in service are repaired readily

by grinding without removing them from the pistons. The piston and rod assembly is mounted in a gap grinder and just enough material removed from the rod to make it round and straight. It usually is brought to a standard dimension so that it will fit metallic packing.

Surface grinding also is employed to advantage in the railroad shop. A rotary platen machine equipped with a magnetic chuck is especially desirable for it can be utilized for finishing a diversity of parts such as the sides of piston rings, link block plates, washers, etc. Guide bar grinding is also a surface grinding operation that is performed on a machine called a guide bar grinder. The work is located usually against two angle iron fixtures and fed back and forth past the face of a cylinder wheel. This operation is productive of much more economical results than are possible by planing and further the surface left by the grinding wheel makes an ideal contact for the cross-head shoes. New guide bars are planed nearly to size and then ground. Old guide bars are repaired by grinding by removing just enough material to take out the worn parts which are developed by the angularity of the main rod forcing the crosshead against the guide bars.

Links are ground on special machines called link grinders. Both built-up and solid links can be ground. Solid links are ground out to fit their blocks and in repair operations, the link is ground out just enough to true it up and a new block fitted. Built up links are repaired readily by grinding by removing a slight amount from the filler pieces at the ends. Then the link is assembled and ground to fit the block.

A large amount of general grinding is performed in the railroad shop usually on large wheels mounted on substantial stands. Tool grinding operations consist of sharpening lathe and planer tools etc., and in sharpening milling cutters, reamers, etc. The former operation can best be performed in the tool room on special semi-automatic tool grinding machines so that the operators simply exchange dull tools for new reground ones, one of the tool-crib boys keeping up the stock of ground tools in his spare time.

Cutter and reamer grinding is performed by regular methods, usually on universal grinding machines of substantial design since the tools employed on railroad shop work are com-

paratively heavy. In general, railroad shop grinding involves special operations so that it is classed as a special branch of abrasive practice. But little has been accomplished in simplifying methods except in the larger shops as production time does not appear to be an important factor in the railroad shop, except in specific instances.

A special grinding operation performed in railroad shops consists of fitting throttle valves in their seats. This is accomplished by hand grinding with carbide of silicon grain and oil, usually 60, 90 and 120 grits. The operation does not differ materially from that of grinding automobile valves in their seats except that it is more laborious owing to the size and weight of the parts.

REAMER AND TAP FLUTE GRINDING

The flutes of taps and reamers can be ground by hand. This requires some skill, but it is attained easily. The wheel should be from 60 to 80 grit in a medium grade and preferably in elastic bond. It is necessary to true the wheel face to the shape it is desired to generate. This is accomplished readily with a hand diamond tool or with a mechanical dresser. The object of grinding the flutes is to enable the tool to cut smoothly, so that all that is necessary to remove is just enough to make a smooth surface. In cases where wheels are not available, the flutes can be polished with abrasive grain mixed with oil and applied with a hardwood stick. This is rubbed back and forth over the flutes. Where reamers and taps are made in large quantities, the work generally is set up between centers for grinding the flutes, although in many instances the hand method is preferred.

REGRINDING AUTOMOTIVE PARTS

The principal operations involved in regrinding automotive parts are grinding worn cylinders, fitting new pistons and rings and regrinding crankshafts. In some instances cylinders are honed in place of grinding but this method is not always practicable. The machine-tool equipment of the average regrinding shop includes a cylinder-grinding machine, universal grinder with attachments for finishing crankshafts (or a so-called auto-parts grinder), drill press, engine lathe, washing tank and testing apparatus and gages.

The washing tank should be large enough to contain the

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largest size cylinder blocks. It should be filled with a sal-soda solution of sufficient strength to leave a white deposit when dry. A bucket of soda to six buckets of water should give good results. The tank should be heated, either with a steam coil or by a fire underneath. The block should be cleaned in this tank before and after regrounding.

Cylinders are ground on special machines provided for the purpose. The work is located on an angle iron fixture, while the wheel spindle is supplied with a planetary movement to regulate the depth of cut. One type of machine, however, is vertical, so that the work is located directly on the platen. In using the horizontal type machine, which is the most common, care must be exercised to make sure that the angle-iron fixture stands square with the wheel spindle. This can be tested with a sweep indicator. With the block in place on the fixture all the bores are reground to one size generally. The kind of wheel to use depends on the nature of the material to be ground. The Heald Machine Co. gives the following data pertaining to wheel selection:

Grade of Cast Iron	Abrasive Co. Electrolon	American Co. Carbolite	Carborundum Company Carborundum	Cortland Co. Cabora
Soft	30-J	36-J	365-P-OF	36-I
Medium	30-I	36-I	303-S-OH	36-H
Hard	30-H	36-I	303-S-OH	36-H
For Steel	Borlon 46-J	Corundum 7736-J	Aloxite 36-P-L6	Oxaluma 36-K
Grade of Cast Iron	Sterling Co. Sterbon	Norton Co. Crystolon	Vitrified Co. Carborite	Waltham Co. Carbowalt
Soft	36-I	36-I	46-H	46 s-I
Medium	36-H	36-H	36-I	36 s-I
Hard	36-H	36-H	36-H	36 s-H
For Steel	Sterlith 36-I	Alundum 3836-I	Borite 46-H	Special Alowalt 36 s-I

Many cylinder grinding machine operators make a practice of truing wheels with an abrasive brick held by hand. Better results can be obtained, however, by using a diamond tool mounted in a holder that is provided for the purpose. The wheel must be true to accomplish the best results.

The machine must be in good condition to insure the pro-

duction of good work. If it vibrates, chattering will result. The spindle boxes must be adjusted correctly and the machine preferably should be set on a firm foundation. If it is necessary to locate the machine on any but a ground floor it should be near the wall or a supporting column.

By exercising judgment the operator can tell how much stock to remove in roughing and finishing. For example, let it be assumed that it is necessary to grind out 0.015-inch. With the eccentric motion operating at its fastest speed 0.004-inch should be removed on the first pass in through the cylinder, 0.002-inch coming out, 0.004-inch on the second pass in, 0.002-inch on coming out, 0.002-inch on the third pass in and 0.001-inch coming out. The wheel is fed through the fourth time with no additional depth of cut.

If the wheel is too hard it will glaze and will not produce round or straight holes. Of the other hand if it is too soft it will break away readily without grinding. In the foregoing list, the wheels listed for hard iron are best for such castings as Pierce-Arrow, Mack and Packard trucks as these cylinders are quite hard. The wheels recommended for medium cast iron will handle 90 per cent of all jobs. Occasionally soft blocks are encountered. On such work the wheels listed for medium cast iron do not cut freely. In this case the eccentric speed should be increased to its utmost capacity and the wheels listed for soft cast iron should be used. Steel cylinders should be ground with the wheels listed for that purpose.

Occasionally a cylinder will have abnormally thin walls due to a core having become shifted when the block was cast. Thus in regrinding, the wheel may break through. This also is true sometimes when the operator attempts to remove an abnormal amount in finishing a cylinder that is scored. It is best to fill the scores with one of the special preparations made for the purpose before regrinding. At any rate a scored cylinder should be reground at the owner's risk only. In cases where a large amount of stock must be renewed the cylinder block may be overheated and when cold the opening will be altered. In this case it is advisable to rough down all holes to within 0.002-inch of the desired size before taking the finishing cuts.

The piston cannot fit the cylinder snugly as clearance must be provided for expansion as the engine heats. No set rules can be given for piston clearances.

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As a general rule it is safe to allow a clearance of 0.001-inch for each inch of diameter for cast iron pistons. However, not all manufacturers favor this allowance. A close allowance is practicable if the fitting of the pistons, rings and piston pins is a first class job performed by a skilled mechanic. Furthermore, assurance must be had that the owner of the reconditioned motor will not exceed a speed of 25 miles per hour during the first 500 miles of driving. If the job is for a racing car or taxicab it is advisable to leave a liberal allowance, say 0.00125 to 0.0015-inch for each inch of piston diameter. Racing cars and motor trucks are subjected to heavy duty so that their engines bear more than do those of pleasure cars. Taxicabs generally are driven recklessly so that it is advisable to take no chances. Piston manufacturers, especially those who market alloy material, can state best what clearance should be allowed in fitting their products. The average regrinding shop cannot make oversize pistons as cheaply as they can be purchased outside.

After the bores are ground the oversize pistons are ground on an autoparts grinder to fit. Then the piston pin holes are reamed and the piston pins fitted. These also can be purchased cheaper than they can be made. It is essential to square the rods on a special fixture provided for the purpose. Otherwise if the rod does not stand square, the piston will not fit its bore correctly. It will bind and cause excessive wear.

The piston rings must fit their grooves freely. If they fit too snugly this can be remedied by rubbing them on a sheet of abrasive cloth placed over a bench block. The gap in the piston rings never must fit snugly. Otherwise the ring will expand in use and score the cylinder. A safe rule is to allow from 0.001 to 0.002-inch clearance between the ends of the ring for each inch of cylinder diameter.

In some instances worn cylinders are honed in preference to grinding them. While this practice may be satisfactory for finishing new cylinders, it is open to question in the regrinding shop. Cylinder hones are appliances fitted with abrasive stones. They are fed through the cylinder bore with a spiral motion while the hone is rotating. The practice of lapping cylinder bores with abrasive and oil is not to be recommended.

Expensive crankshafts can be reconditioned by grinding, but in the case of an inexpensive shaft for a popular-price car, econ-

omy will be shown by installing a new shaft. In regrinding a crankshaft, the first step is to test it to see if the main center bearing runs true. If it runs out the shaft must be sprung to bring it back in as correct alignment as possible. Then the shaft is mounted on offset blocks on a crank grinder, or on an autoparts machine that can be used for this work. The offset blocks must be set to correspond to the crank throw, and the shaft rotated in the offsets to get one of the pins to run as true as possible when tested with an indicator. In some makes of shafts where two pins lie in the same plane this setup suffices for finishing two pins. In grinding the pins, the work should be back-rested and only enough metal removed to clean up the pin.

To scrape in the soft metal main and crankpin bearings of an automobile engine calls for considerable skill not possessed by the average layman. Again, this method is slow and consequently costly. While the so-called method of *burning in* will give satisfactory results in the hands of an expert it is not an operation to be attempted by the average man. Instead of burning in the bearings, he would *burn them out*.

Considerable success has been met with in fitting these bearings with a very mild abrasive compound mixed for the purpose. This material is supplied in paste form and is applied directly to the bearings. For fitting crankpin bearings, the shaft is held in a vise and one rod fitted up at a time. A small amount of the paste is applied to the bearing with oil, after which the bearing cap is bolted in place. The rod is then rocked back and forth until abrasive action ceases and a dull-finished, 100 per cent bearing results.

For fitting the main bearings, a small quantity of the paste and oil is applied and the shaft set in place. Then the bearing caps are bolted in place and the shaft rocked back and forth until a full bearing results. After all of the bearings are fitted, they are taken apart and washed with gasoline.

It is possible to fit up bearings in the foregoing manner without taking the engine out of the car. In this case one bearing should be fitted at a time. With the cap set in place the engine can be turned over by hand a few times. To remove the bearing compound from the upper halves of the main bearings, a cloth saturated in gasoline is held against the shaft as it is rotated slowly.

GRINDING PRACTICE

ROLL GRINDING

Chilled iron and steel rolls are used in various industries for such operations as forming and calendering paper, rolling steel, grinding grain and finishing precious and semiprecious metals for jewelers' use. Jewelers' rolls also are used for making tin foil. Practically all the rolls on a Fourdrinier paper machine are finished by grinding. They include the breast roll, couch rolls, press rolls, dryer drums, calenders and reels. Representative rolls as used on paper machines at the plant of the Champion Coated Paper Co., are of the following dimensions and weights:

Roll	Material	Diameter, inches	Length, inches	Weight, pounds
Breast	Gun metal	18	168	3500
Suction couch	Gun metal	25	168	.....
First upper press	Granite	22	170	6000
Second upper press	Granite	24	170	8400
Third upper press	Gun metal, hollow	24	167	8000
Lower press rolls	Cast iron, hollow rubber covered	26	166	9000
Dryer drums	Cast iron, hollow	48	164	9000
Upper calender	Chilled iron	18	162	12,000
Intermediate		13	162	5500
calender, four	Chilled iron	18	162	12,000
Next to bottom	Chilled iron	28	162	26,000
Bottom				
Reel	Cast iron, hollow	42	166	7000

Super calender rolls also are finished by grinding. These are chilled iron and compressed cotton or paper. They range in face from 60 to 70 inches with 7 to 9 rolls in a stack. A representative stack at the Champion plant weighs from 60,000 to 75,000 pounds. The bottom roll in such a stack weighs from 7000 to 10,000 pounds, the top roll from 5400 to 8000 pounds and the intermediate rolls from 2000 to 3000 pounds. From the sizes and weights of all of the foregoing rolls it is seen that paper mill roll grinding deals with very bulky materials.

Such rolls are finished on a roll grinding machine carrying two wheels. Paper-mill roll grinding is not a production operation. Several rolls of each kind are kept in stock at all times so that worn rolls are exchanged for reground ones. However, the paper-mill roll grinding machine generally is in operation. It is a curious fact that practically one abrasive in one grit and grade is used for grinding all the foregoing rolls. This wheel, two to a machine, is 14 inches in diameter, 1½-inch face, 70

grit, 4 grade, shellac bond, carbide of silicon. Such wheels should be operated at about 5000 feet per minute peripheral speed. The work is mounted on brackets by its journals and turned at an approximate speed of 20 feet per minute. The depth of cut is about 0.001-inch. As may be imagined, considerable time is consumed in grinding some of the large rolls, several days if they are badly worn. The work is cooled by a stream of clear water delivered from the city mains. The rolls must be crowned to offset the sag caused by their weight. The amount of crown may vary from 0.1 to 0.3-inch, depending on the length and diameter of the roll. The roll grinder does not attempt to overcome the sag by getting a straight top to the roll as it rests on its journals. He *overcrowns* it, on the other hand, so that when it is subjected to the weight of the stack it is depressed and no light will show through the joint. Bottom and next to bottom rolls are crowned as also are top rolls in some instances. Intermediate rolls are not crowned. These heavy rolls are arranged in orderly piles on the store room floor under an overhead trolley so that the problem of getting them in and out of the grinding room is met readily.

Steel mill rolls are of various sizes, being made of both steel and chilled iron. For many years they were reconditioned by turning. Of late years, however, the special massive grinding machines developed for the purpose have proven very efficient. In strip mills, hot rolling is done with chilled rolls from 12 to 20 inches in diameter and from 16 to 24 inches long. Such rolls are ground concave. High finish is not necessary in this case. Rolls used for cold rolling must be finished well to produce good work. Such rolls are from 8 to 20 inches in diameter and from 12 to 28 inches long. They are crowned to a slight extent to compensate for expansion due to heat from the journals. Hoop steel is rolled between chilled iron rolls from 6 to 14 inches in diameter and 9 to 18 inches long. Tin plate rolls are chilled iron 28 inches in diameter and 32 inches long. They are finished with a slight concave. Rolls for coating sheet metal with hot tin are alloy steel from 3 to 6 inches in diameter and from 3 to 9 feet long. They are crowned to varying degrees. Sheet steel is rolled between chilled iron rolls 20 to 40 inches in diameter and 44 to 200 inches long. These rolls are crowned.

The foregoing steel mill rolls are finished on special grind-

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ing machines. The grinding wheel must be of a grade and bond to break away readily as the abrasive grains become worn. In general, a peripheral speed from 5000 to 6000 feet per minute is recommended. The work speed should be about 60 to 70 feet per minute. This can be increased to 90 or 100 feet per minute for finishing. The wheel should be trued with a diamond with a slow traverse speed. The roll is located from its necks or journals. These must be round, for if they are not, accurate results on the roll face cannot be assured. If the journals are worn out of shape, the roll should be located between centers and the journals ground true. In comparing roll grinding and turning, S. S. Shoemaker gives the following data, which was obtained from a number of representative steel mills:

Diameter of roll, inches.....	28
Length of roll, inches	32
Depth of chill, inches	$\frac{3}{4}$
Approximate cost of new roll.....	\$ 400.00
Approximate salvage price of used roll.....	100.00
Net cost of roll	300.00
Value of metal saved by grinding.....	3.20
Cost of turning a roll, 3 hours at 70 cents per hour.....	2.10
Cost of grinding a roll, $\frac{3}{4}$ hour at 50 cents per hour.....	1.71
Total savings	4.91
Approximate cost of 30 x 96-inch roll grinder installed.....	16,000.00
Interest on investment at 6 per cent.....	960.00
Depreciation of grinder at 10 per cent.....	1600.00
Yearly cost of the investment.....	2560.00
Interest on the investment at 6 per cent.....	330.00
Depreciation of the machine at 10 per cent.....	550.00
Yearly cost of a roll lathe investment.....	880.00
Net yearly cost of grinding machine investment.....	1690.00

Summary—

- Grinding 30 rolls a week saves \$7659.00 per year, or 37 per cent of the investment.
- Grinding 50 rolls a week saves \$12,766 per year, or 69 per cent of the investment.
- Grinding 100 rolls a week saves \$26,532 per year, or 149 per cent of the investment.

The chief saving by grinding these large rolls is that only enough need be removed to true up the roll. Thus the chill, the vital part of the roll, is conserved as much as possible. When rolls are turned enough material must be removed to enable the tool to cut properly.

Rolls for rolling tin and other foil are hardened steel. They are ground in cylindrical grinding machines generally, as this work is a precision operation. Such rolls are from 3 inches in diameter and 5 inches long to 14 inches in diameter and 19

inches long. They are forged steel and rough ground with a wheel in 24 combination grit, K grade. They are finished with an XF grit, I grade, carbide of silicon wheel. Formerly such rolls were finished by lapping with emery. This is a long process. In the finishing operation with the fine-grit abrasive wheel, the cooling medium is water and it must pass over the roll once only to make sure that all grit is removed.

Seed-crushing rolls are used for crushing cotton seed principally. They are either chilled iron or steel and are mounted one above another in various combinations. Usually the stands are five rolls high with rolls from 12 to 18 inches in diameter and from 48 to 72 inches long. The lower roll is the largest and sometimes is termed the backing roll as it supports the others. Two methods are followed in grinding these rolls. They are supported on their centers or by their journals. The latter method is preferred. They are ground on either of two types of machines, that is, regular cylindrical grinders or roll grinders carrying two wheels. In grinding on a cylindrical machine, the rolls usually are rotated at a surface speed of from 100 to 200 feet per minute. The grinding wheel is approximately 30 inches in diameter with a 3-inch face. Carbide of silicon wheels are used for finishing chilled-iron rolls and alumina oxide for steel rolls. The wheel travel is about $\frac{1}{8}$ -inch advance for each revolution of the work.

Grain grinding or flour mill rolls run from 6 inches in diameter and 15 inches long to 10 inches in diameter and 42 inches long. They are chilled iron. Corrugated rolls are used for breaking wheat and smooth ones for grinding middlings. The rolls become worn through constant use. With the corrugated ones it is necessary to grind away the old corrugations and to place new ones in place on special machines. With smooth rolls, all that is necessary is to remove enough material to true them up. Two types of machines are used for finishing these rolls. That is, cylindrical grinders and special roll grinding machines. When the grinding is performed on a regular cylindrical grinder the operation does not differ materially from that of grinding oil crushing rolls. In finishing the rolls on a roll grinding machine equipped with two wheels, the work is located by its necks or journals and rotated at a speed of about 35 feet per minute. The wheels are operated at a surface speed of 5000 feet per

minute. The grinding is performed wet, city water usually being used. The wheels are carbide of silicon, 10 inches in diameter, 1½-inch face, 30 grit, medium grade, shellac bond. The elastic bond is said to give economical results in grinding away the worn corrugations. This is not a production job in the strictest sense of the word, as one man can attend to two or three roll grinders and as many corrugating machines at once. Some of these smaller roll grinding machines operate on the swing rest principle while others do not.

ROLL SCOURING

In the operation of rolling sheet metal, it is necessary to remove imperfections from the rolls frequently. Otherwise a smooth and uniform product cannot be secured. This is performed by an operation called *roll scouring* with special shape abrasive bricks, a popular form being shown in Fig. 45. Practice

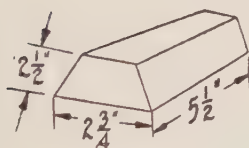


FIG. 45—ABRASIVE BRICK
FOR ROLL SCOURING

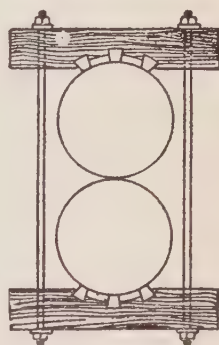


FIG. 46—DEVICE FOR
HOLDING ROLL
SCOURING BLOCKS

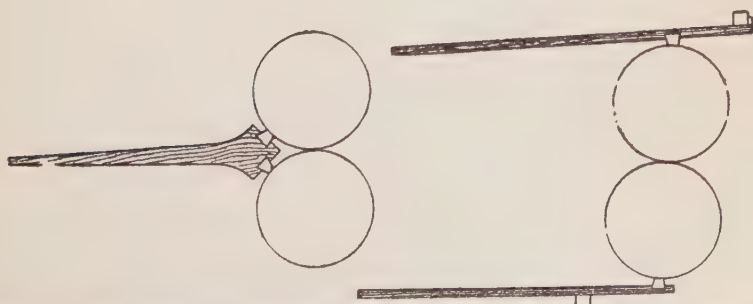


FIG. 47—TWO SIMPLE METHODS FOR HOLDING ROLL SCOURING BLOCKS

of applying the bricks differs in various mills. The arrangement shown in Fig. 46 has been used with good results. It consists of a stout oak frame held together with tie rods, the bricks being held as shown. Pressure is applied by setting up the nuts on the tie rods. This device is used extensively for cleaning the so-called cold rolls, or rolls used for producing cold-rolled material. In the operation of roll scouring, the rolls are lubricated with palm oil as the yoke is fed back and forth across them.

The arrangements shown in Fig. 47 are used for scouring rolls for finishing hot stock. In the illustration at the left the blocks are held in wood levers which are brought against a fulcrum. In the device at the right two bricks are held on the end of a long lever so that they bear on the top and bottom rolls simultaneously. The grits used vary in different plants, 60 and 90 being favorites for scouring hot rolls. For taking out very deep scores, however, 36 grit is preferred. For finishing cold rolls 80 and 90 grits give good results.—A. B. Davenport, Jr.

SAD-IRON GRINDING

For many years the bottoms of sad irons were finished by locating them in a lathe chuck and facing them off with a turning tool. In some instances multiple lathes equipped with six headstocks were used so that six irons could be in process of finishing simultaneously. More economical results, however, are attained by grinding. One method extensively followed consists of disk grinding. The iron is held in a special fixture and rocked back and forth past the disk face. The disk should be carbide of silicon, 16 to 24 grit. Sad irons also have been ground economically on vertical spindle grinding machines equipped with ring wheels. In this case a number of irons can be located at one setting. After grinding the irons must be polished highly. Generally this is done on wood wheels faced with leather and set up with emery. The grit numbers vary, but No. 80 followed by 120, then flour is a good combination. The last wheel is greased.

SAFE GRINDING

Abrasive operations are followed extensively in the manufacture of safes and bank vaults and in many instances the grinding equipment is specially constructed. Plates generally are edged by grinding, one type of machine employing a traveling

wheel head fitted with a cylinder wheel while the work is strapped securely on the machine bed. Plates are surfaced with both solid and setup wheels. The former is probably the more efficient for roughing operations, that is to remove the scale and surface imperfections. Subsequent operations constitute technically a polishing job which can be performed to the best advantage with setup wheels.

Round bars for grills, etc., sometimes are polished with polishing clamps and abrasive cloth, but better results undeniably are obtained by using a belt polishing machine which will produce five times as much work in a given time than is possible to turn out by the hand method. Large circular doors and their frames are ground generally on huge boring mills with an abrasive wheel arranged on a wheel head on one of the tool slides. The process is slow, the production time being governed by the size of the work.

In the manufacture of globular manganese steel coin safes, grinding must be relied on wholly, as this material cannot be machined by other methods. Door openings are ground by locating the same on a special machine generally horizontally, although modified boring machines have been used for this purpose. The work must be ground to close dimensions. The doors also are ground by locating them on a face plate fixture or on a boring mill adaptation. After the parts are ground they are lapped together with carbide of silicon to make a tight joint. This is necessary as a slight opening would enable the professional bank burglar to introduce nitroglycerin. Hence a high degree of accuracy is necessary. In the lapping operation carbide of silicon and oil is placed between the parts and the door in position is oscillated back and forth for several hours by a mechanically operated arm.

SAW GRINDING

The sharpening of band and circular saws generally is referred to as saw filing, taking its name from the time when files were used exclusively for the work. For the same reason, one who grinds band saws is called a saw filer, while the operation is styled saw gumming. The wheels employed are called saw gummers.

The location of the filing room is of the utmost importance. Generally it is placed just off the main mill so that the saws

can be handled readily. However, this location possesses a disadvantage in that the filing room is subjected to considerable vibration. By housing the filing department in a separate building, connected to the mill by a covered bridge, the vibration can be eliminated. This will result in better work.

Another point that is not always given consideration is the manner of driving the filing department machinery. If the drive is from the same source of power that supplies the mill, usually a steam engine, the extra load thrown on the engine when a huge band saw strikes a log slows down the power before the engine governor has a chance to act as a compensator. A few revolutions less per minute make no difference to the sawmill. but when it slows down the grinding wheel on the saw gumming machine it makes the wheel act soft and thus reduces its life and cutting efficiency materially. A better plan is to drive the filing room machinery by a separate steam engine or an electric motor. By this means constant speed is assured.

Saw gumming machines are of two types operating on the same principle. One kind handles band and the other circular saws. In both types the wheel head is set at an angle and mechanical means are employed to raise and lower the wheel as the saw is pushed forward, tooth by tooth, by the feed dogs. As a general thing, the saw filer performs two operations on saws, that is, tension and grinding. Another operation performed occasionally is lap grinding. Saws are tensioned by rolling them through a saw tensioning device, a machine equipped with two rollers and means for exerting pressure. Sometimes saws are hammered for the same reason. Tensioning is an exacting operation for if it is not correct, the saw will not operate correctly.

In saw gumming, the operator performs two operation which he terms roughing and pointing. The latter operation is simple, as a few cuts around the saw are sufficient in most cases. After a saw has been in use for a time, however, it must be swaged to give the teeth the proper clearance and then repointed. Swaging is performed with a special device, generally a hand-operated tool that swages one tooth at a time.

When a saw is in a poor condition with a number of teeth ripped out from coming in contact with spikes, nails or other metallic substances imbedded in the wood, new teeth must be ground in place. This is a comparatively long operation as the

saw must be gone around many times. However, as the saw grinder is automatic in operation it can run for hours at a time with no attention save an occasional letting down of the wheel to control the depth of cut.

Wheels for saw grinding should be free cutting and not too fine. Fine wheels glaze as also do hard ones. This causes the temper to be drawn from the teeth and also it produces case hardening which develops cracks. Unsuitable wheels will ruin good saws in a very short time. The grit and grade to select depends on a number of local conditions and the best wheels for specific purposes can be determined only by tests as local conditions must be taken into account in nearly every case.

Opinions vary as to the best type of wheel to employ. In the southern part of the United States, vitrified bond wheels are preferred. On the Pacific coast elastic bond wheels find the most ready sale for grinding the comparatively heavy saws used in that district. Thus wheel selection is a matter of opinion.

Lap grinding consists of grinding the ends of a band saw tapered before it is brazed together. This operation is performed on a special machine called a lap grinder. The operation is not a complicated one by any means but wheels graded for the purpose should be used instead of a discarded stub of a saw gumming wheel as in common practice. The operation is simple. The saw is held in a clamping device and which locates it at an angle and fed back and forth under the wheel. This is continued until the bevel is ground satisfactory. Then the other end is ground. Care must be exercised to get the bevels on the correct sides of the saw for otherwise they will not join properly.

SAW-MILL WHEEL GRINDING

When a band saw mill is in continuous use, the wheels wear rapidly so that they must be refaced at least once a year, according to J. D. Ge Bott. If the scrapers are not adjusted properly to the wheel faces, the wear will be more rapid than it should be. The dirtier the lumber cut, the more wear of the mill wheels. The lower wheel wears more rapidly than the upper one as dirt from the timber drops between this wheel and the saw. This causes the front of the wheel to wear rapidly which makes the saw run slack at the cutting edge. A band mill wheel generally wears in two places only. The wear is found on the

extreme front edge and back from this edge about three inches. A hollow place is worn where the back of the saw rides on the wheel. It runs high from this point to the back edge.

Band-saw mill wheels generally are finished flat, but some mill men advocate a slight crown. Under either condition both edges of the wheel should be alike when measured with an accurate steel tape. To remove the wheel from the mill for re-grinding would necessitate a costly operation so that special devices are utilized. Such a machine embodies means for locating abrasive blocks in a holder and feeding them past the wheel face. The device is made to locate on the mill in close proximity to the wheels to be finished.

Before grinding the lower wheel, it should be tested to make sure that it is level and if out of line it should be reset. Attention also should be given the journal boxes to see that they are set up correctly. The grinding device then is set square and level and the blocks fed past the wheel face until all irregularities are ground away. It is obvious that the wheel should be cleaned thoroughly of dirt and gum before the repair operation is begun. In some instances a cup wheel is substituted for the abrasive blocks. This wheel is driven by the action of the revolving band wheel. It operates at a speed of approximately 5000 feet per minute. It takes about an hour to rig up the arrangement and about five hours to grind one wheel. When grinding the upper wheel care must be excided to clamp the straining device securely.

SHEAR-BLADE GRINDING

Shear blades as used on various machines for cutting metal sections are sharpened on knife grinding machines. The knife bar is adjusted to impart the necessary angle. Special machines called shear blade grinders also are used for the purpose. The grinding should be done wet. In some instances shear blades are sharpened by hand by locating them on a flat rest set at an angle and feeding them past the wheel face.

SHOVEL GRINDING

Shovels are cut to shape between cutting dies and then forged between chilled iron dies. Abrasive operations in their manufacture consist of edging and polishing the blades and polishing

the straps and sanding the handles. Shovels are edged with hard-grit wheels, usually from 20 to 24 inches in diameter. Generally two polishing operations are performed, before and after tempering. Muslin wheels about 20 inches in diameter set up with No. 46 and No. 90 Turkish emery or aluminum oxide are used. While a high polish is not necessary the surface must be smooth and attractive. After the handles are inserted the shovel straps are polished on the same type of muslin wheels used for finishing the blades. The handles are put over four belts. The first belt is set up with No. 90 emery or aluminum oxide. It is used on the straps only. The second belt is set up with quartz or garnet about $2\frac{1}{2}$ grit, the third belt is set up with No. 1 material while the last belt is waxed only. The flat parts of D-handle shovels are sanded on a muslin wheel set up with No. 1 quartz or garnet.

SKATE GRINDING

Skates are ground by locating them in a holder and feeding them by hand past the periphery of a grinding wheel. The holder is moved back and forth over a table provided for the purpose, the table being adjusted so that the skate blade will be ground in correct relation to its vertical axis. The periphery of the wheel, of course, leaves the skate slightly hollow ground which condition is generally desired. One model of the Ferodo-will grinder is fitted with a device for forming a concave wheel face so that hollow grinding can be done with a so-called lengthwise finish.

SKIING MACHINE KNIFE GRINDING

The circular cutting knife on a skiving machine must be sharp at all times. These knives are sharpened as occasion required by a means of a grinding wheel located on the skiving machine for this purpose. The wheel spindle is set at the required angle and grinding is performed with a saucer wheel.

SPRING GRINDING

The ends of coil springs must be ground flat and true. Several methods are followed. For example, ordinary size springs are held in a fixture, usually a V, and fed past the face of a cup or cylinder wheel. In some instances the flat side of an ordi-

nary wheel is employed but this is not good practice. The ends of very small springs often are ground by hand. The very large coil springs such as used on railway equipment are ground by holding them in special fixtures and feeding them between two cylinder wheels on a double-head grinder. One recently developed machine for this purpose carries wheel 24 inches in diameter. The machine weighs 14,000 pounds. The coiled ends of flat springs such as used in automobile construction also are ground by passing them between two wheels. Usually the spring is located in a special holder. Vitrified wheels in about 24 grit give the best results on spring grinding. Springs of ordinary size, such as automobile-engine valve springs and similar units, often are ground to advantage on a double-disk grinding machine fitted with thick abrasive circles. The work is loaded into a carrier which is placed between the wheels. As these machines generally are equipped with an automatic feed, the operator can load one work holder while the grinding operation is in progress. The tension of the springs make their own grinding pressure.

SQUARE HOLE GRINDING

In general, this is an expensive operation as the grinding proceeds slowly. It is performed on a special machine fitted with an arm which carries the grinding wheel. The parts necessarily must be fragile to enable to permit the grinding of small holes. The wheel is driven by a round belt. It is of the cup variety and rotated at high speed. It is fed in and out of the work automatically. The work is located in a work head that can be indexed to generate the four sides. Such machines also are used for finishing hexagon and other multiple side holes.

STELLITE GRINDING

Stellite is an alloy steel used for turning and boring. The edge strength of such tools, according to the Haynes Stellite Co., is not as great as that of steel. Thus the edges must have adequate support. Machine grinding is to be preferred to off-hand grinding. Care must be taken to avoid checking. Wheels must not be forced to cut or overheating will occur. Light cuts should be taken and dry grinding is preferred to wet. Stellite tools should not be doused in water while grinding. The sudden chilling will cause checks. Avoid heavy grinding on the top of

GRINDING PRACTICE

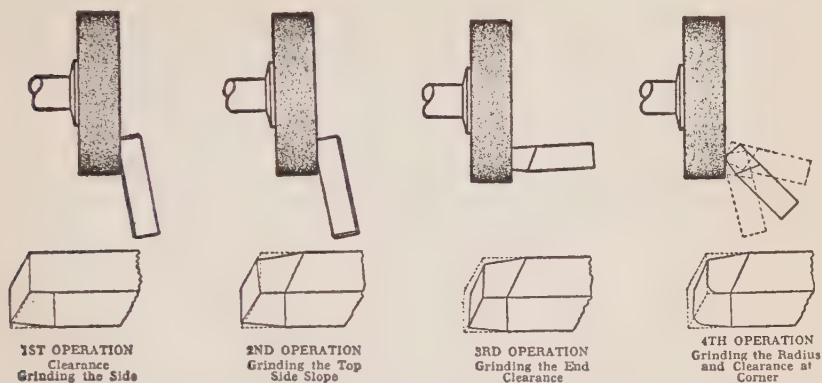


FIG. 48—CORRECT METHOD FOR GRINDING STELLITE TOOLS

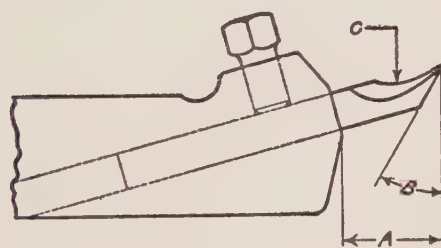


FIG. 49—THIS TOOL IS NOT GROUND CORRECTLY

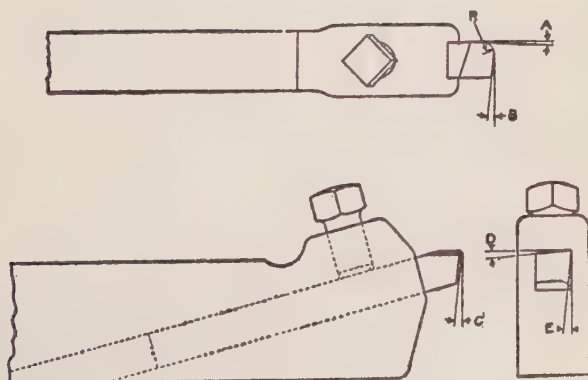


FIG. 50—CORRECT METHOD OF TOOL GRINDING

the tool. Do the grinding on the end and side. Grind on the side of the wheel—not on the periphery. Correct cutting angles are necessary. For cast iron a side slope of six degrees toward the chip (not toward the work) is most efficient. This slope is best obtained by adjusting the angle of the tool holder or seat of the tool—not by grinding the top of the tool. For steel, a side slope of 8 to 10 degrees is necessary. In Fig. 48 is shown the right

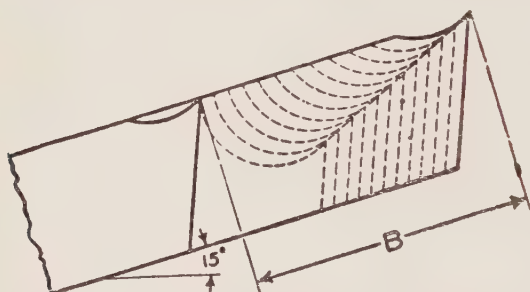


FIG. 51—STOCK IS WASTED BY GRINDING IN THIS MANNER

way to grind stellite tools. Give the tools all the edge support possible and grind only the necessary minimum clearance. When possible use cup or cylinder wheels. When these are not available use the flat side of an ordinary wheel. After grinding, remove the wire edge with an oil stone. In Fig. 49 is shown an

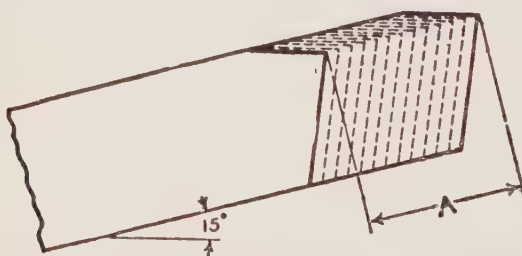


FIG. 52—THIS GRINDING METHOD CONSERVES STOCK

incorrect application of a stellite bit in a tool holder. The overhang, *A*, is excessive, clearance angle, *B*, is incorrect and the top grind, *C*, is unnecessary. This bit is too fragile to do good work. A correct application is shown in Fig. 50, wherever *A* is five degrees, *D* is six degrees, for cast iron and 10 degrees for steel, *B* is four degrees, *E* six degrees, *C* six degrees and *R* equals

$\frac{2}{3}$ of the depth of cut. Stellite should not be ground with a lip on the top of the tool. In Fig. 51 is shown the incorrect way to grind. This method will result in failure, although it often is followed in grinding high speed steel tools. The correct method is shown in Fig. 52, using the so-called end grind. A slight top grind is required on account of the 15-degree angle of various standard tool holders designed for high speed steel.

In Figs. 51 and 52, an equal number of grinds are shown. The tool showing the correct method retains its original cutting profile length at A. In the illustration showing the incorrectly ground tool, the entire end must be ground away to regain the original cutting profile. The waste of material is shown clearly by comparing dimensions A and B in the illustrations of the correct and incorrect methods.

STOVE-PLATE GRINDING

Stove-plate grinding is divided roughly into three operations as follows: Grinding the edges of sections to make the parts fit correctly, grinding out grooves in latches for doors, etc., and surfacing the tops of assembled stoves. Grinding the sections to make them fit is essentially an offhand operation. Stove fitters become very expert at this work. Vitrified carbide of silicon wheels are used almost exclusively. Latches are ground out with thin rubber-bond wheels. This also is an offhand grinding operation. Surfacing generally is performed on a special machine. Stove-plate grinders can be purchased, but no end of home-made appliances are in use. Usually a carbide-of-silicon wheel with a comparatively wide face is used for roughing down, while the final finishing is performed with polishing wheels.

SURFACE GRINDING

As stated in Section VII, there are twelve types of surface grinding machines so that surface grinding practice depends to a large extent on the type of machine employed. Surface grinding procedure on the first type of machine mentioned, where a disk wheel is used in conjunction with a fixed platen, is generally termed spot grinding. The depth of cut is controlled by adjusting the platen vertically and it seldom exceeds 0.001-inch. Grinding is performed by passing the work under the wheel by hand first lengthwise, then crosswise and then diagonally. Very ac-

curate results can be obtained in this manner. For example in grinding hardened size blocks 0.0005-inch is sufficient in many cases to remove the wheel marks. Such pieces generally are held in a little fixture so that they can be passed under the wheel readily.

Machines employing a fixed platen with a traversing cup or cylinder wheel sometimes are called traverse grinders. They are excellent machines for finishing bulky pieces such as safe and vault parts. Such a machine essentially works on the edges of the parts to be ground. Thus its capacity is governed by the diameter of the wheel, as means for changing the relation between the work table and the wheel spindle seldom are provided. In operating such a machine, the work is placed on the table and shimmed up to make it set level. Then it is clamped in place with straps usually. Bunter blocks also should be provided to keep the work from shifting. The edge to be ground should be located as near parallel as possible with the wheel travel. As machines of the type in question are generally substantial, deep cuts can be taken. Thus from a production point of view they compare favorably with the planer or miller, even when working on soft material.

When the design of the machine embodies a reciprocating platen and a disk wheel mounted on a horizontal spindle, quite a range of work can be accommodated. Such machines are used both in tool room and production practice. The easiest method for locating flat work is to use a magnetic chuck. If such a chuck is not available, the work must be held in a shoe with pinch clamps against parallels, or it can be strapped to the platen. The magnetic chuck simplifies locating the work to such a great extent that it is hard and unusual to find a surface grinder that is not thus equipped. To depth of cut seldom exceeds 0.001-inch. The traverse feed ranges from a few thousandths of an inch to 1/8-inch for each reversal of the platen, depending on the design of machine.

When a machine with a reciprocating platen is equipped with a cup or cylinder wheel, one advantage is apparent as the wear of the wheel in getting across the work is eliminated. With the type of machine under consideration the work generally is located on a magnetic chuck. These machines are used advantageously on both tool room and production work. In oper-

ating such a machine the automatic feed usually is set to feed the wheel down a slight amount, say from 0.0005 to 0.001-inch for each reversal of the platen. Plenty of grinding lubricant should be used and the wheel should be dressed, at the first sign of glazing. For locating odd-shape pieces such machines can be fitted with special fixtures. As a rule, however, 95 per cent of the work can be ground on a magnetic chuck.

Machines with a reciprocating platen and a cylinder wheel mounted on a horizontal spindle are rapid producers. Such grinders, called side surfacers, can be used more economically than a miller or planer on almost any type of work. The wheels are massive; 30 inches in diameter and greater. They usually are made in sections to minimize breakage, both in manufacturing and shipping. The work must be located on angle irons in many instances although special angle-iron magnetic chucks often are substituted for plain angle irons. Special fixtures can be provided for locating odd-shape pieces. These machines can take deep grinding cuts as they are exceptionally rigid. Grinding is performed wet while the wheel is trued with a special device that feeds a star wheel dresser over the wheel face.

Two types of machines are fitted with cup or cylinder wheels mounted on vertical spindles for use with rotary platens. The simplest type is called a single-stroke grinder from the fact that one stroke of a hand lever performs the grinding. On such a machine the work, such as milling saws or washers, is located on the platen, the platen started and the wheel fed down to a stop by a hand lever. The wheel is raised and the work removed. A slight adjustment, of course, is necessary occasionally to compensate for wheel wear. These machines essentially are production units, although in a large tool room their installation would be justified. Late types of these machines can be operated to advantage on production work as many refinements are included such as the automatic closing and opening of the electric circuit to the chuck, automatic control of the chuck rotation and automatic rising of the head when the work has been ground to a predetermined thickness. The larger machines, Blanchard grinders, are essentially production machines. The work is located directly on the chuck in the loading position, then the chuck is fed under the wheel and the wheel lowered to the grinding position when the automatic feed

is thrown in. As soon as the work reaches a predetermined thickness, the feed is thrown out. Nonferrous substances cannot be held by magnetic attraction so they are located in special fixtures or on vacuum chucks. Automatic machines of this type also are employed. They locate the work, grind it, discharge it, demagnetize it and then wash it. They also compensate for wheel wear. They are production machines of the highest order. The operation of such a machine is largely a matter of routing once it is understood.

When a rotary platen is used in conjunction with a disk wheel mounted on a horizontal spindle, the effect of wheel wear is reduced to a minimum. Such machines in both the small and large sizes are production units. The operation of these grinders is simple and needs no comment. The smaller types of machines also are equipped with automatic means for locating, grinding and discharging the work. For finishing the sides of piston rings, washers, etc., rotary-platen machines generally show high economy.

The operation of the so-called oscillating grinders, whether the work or wheel is the oscillating medium, is largely a matter of routine as the wheel speed, work speed, etc., is controlled definitely.

In general, surface grinding is not as complicated a procedure as cylindrical grinding. In the latter case, the work speed and wheel speed often must be adjusted to suit local conditions, the wheel, etc., with surface grinding, wheel and work speeds generally are constant. Thus, once the wheel is adapted to the work, little operating trouble should be experienced. Surface grinding should be performed wet when possible. A number of methods are followed for gaging the work. Some machines are fitted with special gages for determining when the work has reached the necessary thickness. Again, some operators rely on the down-feed graduations. The practice of coating one piece of finished work with copper, and putting it in place with the others is sometimes followed. As soon as the wheel removes the copper, the work is very nearly to the desired size. The work should be demagnetized if it has been ground on a magnetic chuck. As before stated, one type of machine demagnetizes its work, but in general this is a separate operation performed with appliances provided for the purpose. In ball bearing manufac-

ture it is of the utmost importance to demagnetize the work thoroughly, for slight particles of metal dust would otherwise be attracted which would soon wear the bearing out.

The grinding of square shafts and holes in gears and other parts is a special surface grinding operation. In grinding squares on shafts the work should be located between dividing centers. Then the wheel is fed to the work and a chip taken off one surface. The work then is indexed 180 degrees and another surface ground. Measuring with micrometers then will reveal how near the work is to the finished size. The four surfaces then are ground one after another. Hexagonal shafts are ground in the same way with the exception that six instead of four sides must be finished.

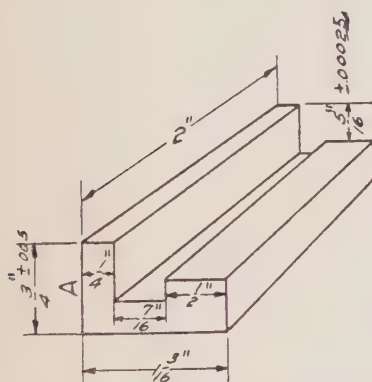


FIG. 53—CASE HARDENED PART TO BE FINISHED BY GRINDING

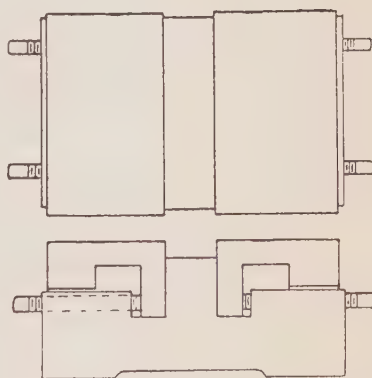


FIG. 54—FIXTURE FOR LOCATING WORK FOR GRINDING

Production costs on precision grinding operations can be reduced in many instances by providing simple fixtures for holding the work and employing the correct grinding equipment. The part shown in Fig. 53 can be considered as a practical illustration. The piece is machinery steel, case hardened, with the lower and two upper surfaces finished accurately by grinding. The former method followed in finishing these pieces was to grind them singly. Each piece was held in a vise on the surface grinder for finishing the bottom. After a lot of 100 or so had been finished, the upper surfaces were ground by setting them, three at a time, on a magnetic chuck. Considerable difficulty was encountered in maintaining the 5/16 dimension within the

prescribed limits. The production cost was excessive as it took 20 minutes to finish each piece.

A more practical grinding method was devised which reduced the production time to four minutes. After case hardening, the surface, A, Fig. 53, was cleaned on a disk grinder. No difficulty was experienced in holding the pieces against the disk by hand. The amount of metal removed was slight, while the purpose was to produce a flat locating surface for setting the pieces in place in the fixture shown in Fig. 54. Four of these fixtures, each carrying two parts, were located at one setting on a rotary-chuck surface grinding machine equipped with a disk wheel. Eight fixtures were provided so that the

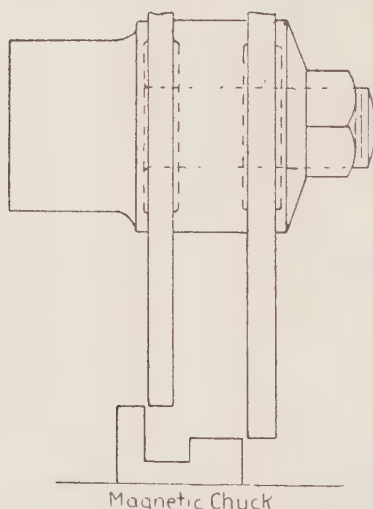


FIG. 55—GRINDING TWO SURFACES
SIMULTANEOUSLY

operator could load and unload four while the others were in place on the machine. Thus, the loading and unloading time was eliminated entirely from the production costs. In this operation about 0.001 inch of metal was removed.

Fig. 55 shows the novel arrangement employed for grinding the two upper surfaces. The pieces were located four in a row on a magnetic chuck. Two wheels, each $\frac{1}{4}$ -inch thick, were mounted as shown. One wheel was 6 inches in diameter and the other, $4\frac{3}{8}$ inches in diameter. The spacing collar between the wheels was of sufficient width namely, $\frac{11}{16}$ -inch, to permit both wheels to begin to cut at the same time. As Fig. 55 shows,

the wheels with the spacing collar between them are located on a special holder that was made to fit the surface grinding machine spindle nose. Thus one wheel works on each surface so that the both are ground at one setting.

To maintain the 5/16-inch dimension correctly it was necessary to exercise special care in truing the wheels. This was successfully accomplished with the device shown in Fig. 56, which is a diamond nib set in a cast iron block and held in place with a set screw. The method followed was to true-off the small wheel at the back and then, by the wheel-elevating screw graduations, the wheel was raised 5/16-inch and the large wheel trued. In the truing operation care had to be exercised to get the diamond point as nearly under the bottom of the wheel as possible.

With the appliances shown the grinding time on these pieces was reduced to four minutes each, divided as follows: rough

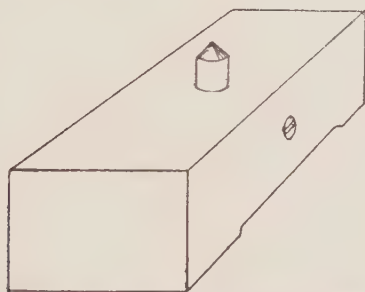


FIG. 56—SIMPLE DEVICE FOR WHEEL TRUING

grind bottom, 3 seconds; finish grind bottom, 30 seconds; grind top, 3 minutes and 25 seconds. The grinding time for finishing the bottoms was reduced materially by finishing the eight parts at one setting in the four fixtures described.—Richard D. Jacobs.

Richard F. Moore supplied the following data pertaining to the accurate surface grinding of a small knife-edge square.

The greatest difficulty encountered in making the square shown in Fig. 57 is to get the two knife edges parallel. At the right is an enlarged end view of the blade. I obtained excellent results recently in finishing a knife-edge square by the method illustrated in Fig. 58. The blade was hardened, rough-ground and thoroughly seasoned. Then it was finish-

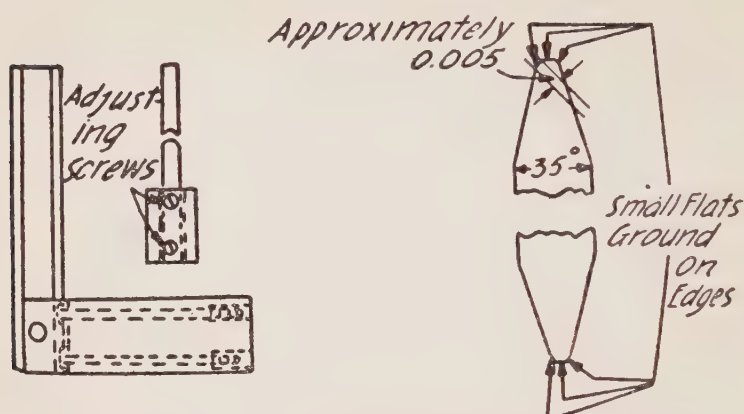


FIG. 57—KNIFE-EDGE SQUARE TO BE FINISHED ACCURATELY BY GRINDING

ground and lapped. Then it was located on the magnetic chuck of the surface grinding machine, as shown in Fig. 58 at the left. Surface, A, was located with a very sensitive dial indicator to make sure that it was in exact alignment with the longitudinal ways of the grinder.

A fairly hard wheel previously had been dressed as shown at the right in Fig. 58, which illustration also explains how the three flat surfaces were finished at one setting of the work. It is a rather delicate job to grind the 45-degree angles, but the way to do this is to come as near as possible with the cross feed and then to use the vertical feed, which has a much finer control. After one side was finished, the blade was turned over for grinding the other side. After the grinding is complete, a skilled gage maker can lap off the corners shown at X, Fig. 58,

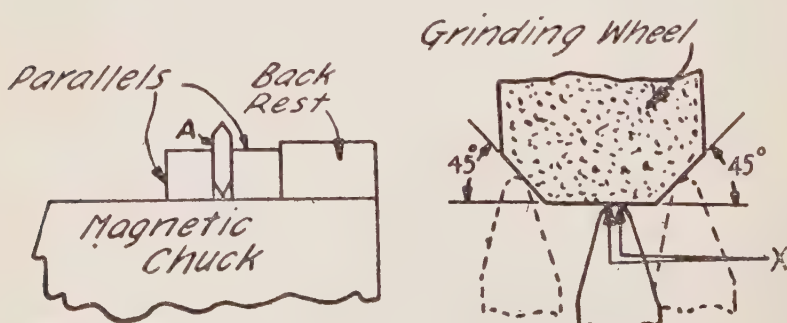


FIG. 58—METHOD FOLLOWED IN GRINDING A KNIFE-EDGE SQUARE

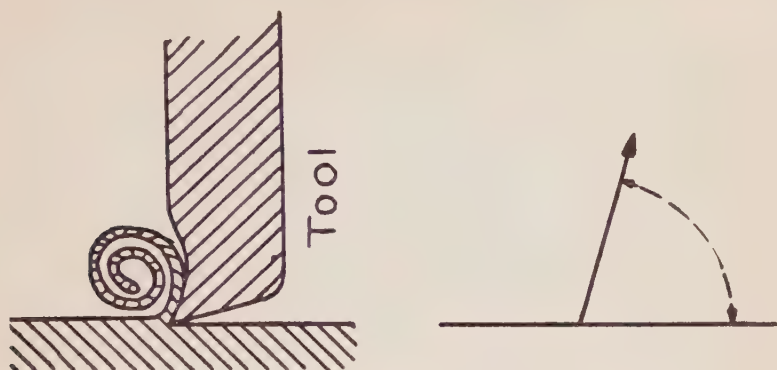


FIG. 59—HOW AN ORDINARY METAL-CUTTING TOOL GENERATES A CHIP

and the grinding marks on the six flats. This operation can be performed without altering the accuracy of parallelism.

The chief reason for the satisfactory performance of recent grinding machines of the type wherein the grinding is done by the flat face of the wheel rather than its periphery, is due to their great rigidity and high power, according to Alan A. Wood. Such machines necessarily bring about great pressure between wheel and work. The area of contact is usually large and the pressure per square inch must be great enough to force many thousands of the abrasive grains into the metal. Even when there is a large amount of cooling solution used, much heat is developed at each particular grinding point. A certain amount of heat, however, aids in the formation of the helical chip. These chips are crushed almost at once and their bulk tends to force

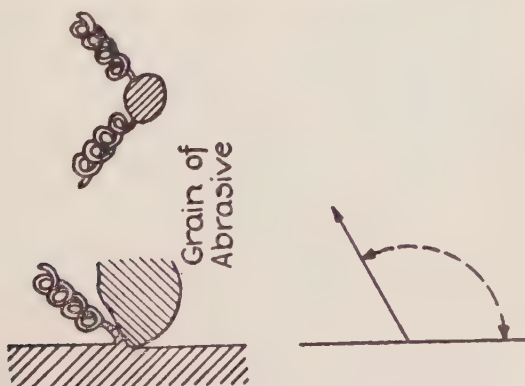


FIG. 60—HOW AN ABRASIVE GRAIN FORMS A HELICAL CHIP

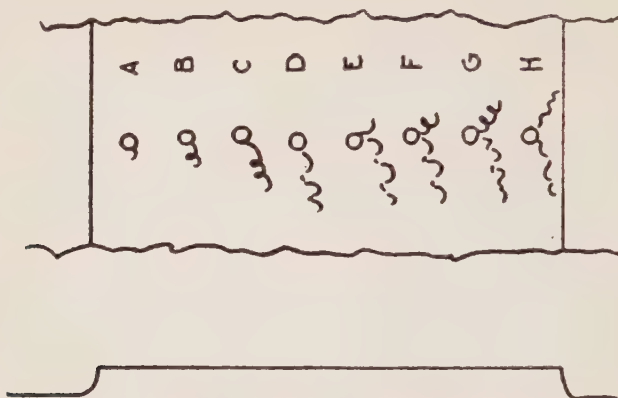


FIG. 61—ABRASIVE ACTION IN GENERATING A CHIP

the wheel away from the work. The friction developed by these chips adds much to the power required for driving.

Chip action is illustrated in Figs. 59 and 60. Fig. 59 shows how an ordinary metal cutting tool generates a chip like a clock spring. Such a tool has a cutting angle of less than 90 degrees, as the illustration shows. Fig. 60 shows how a typical abrasive grain, which has a greater cutting angle than 90 degrees, forms a helical chip. In Fig. 61 the abrasive action is shown clearly. At A, a grain of abrasive starts to make a helical or cork-screw chip, and at B and C this chip lengthens. The chip breaks off at D and crumbles. At E, a second chip begins to form, the crumbles of the old chip remaining. At F and G,

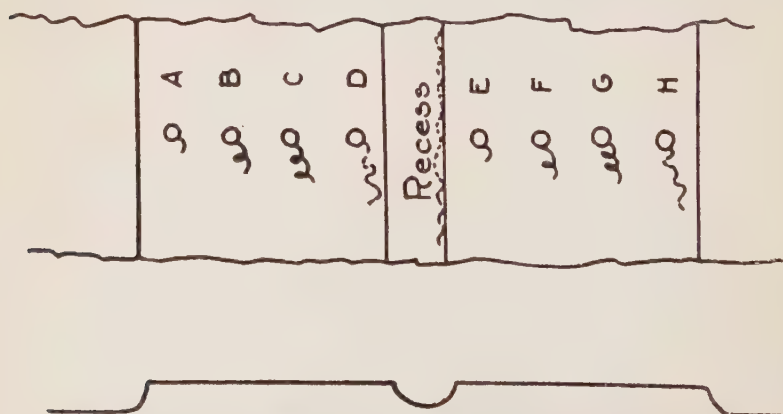


FIG. 62—HOW A SEGMENTAL WHEEL AFFORDS CLEARANCE

GRINDING PRACTICE

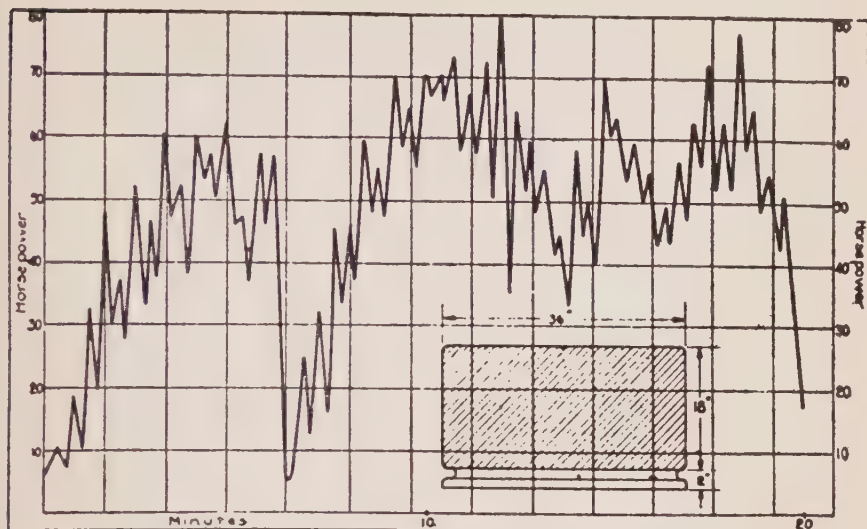


FIG. 63—HORSEPOWER REQUIRED TO GRIND A TYPICAL FLAT SURFACE

the second chip lengthens, the old crumbles remaining. A new chip begins to break at *H*, the old crumbles remaining. This cycle is repeated many times during each passage of each grain across the work. Thus an intense pressure is generated between the wheel and the ground surface.

The segment-type wheel is believed to possess advantages,

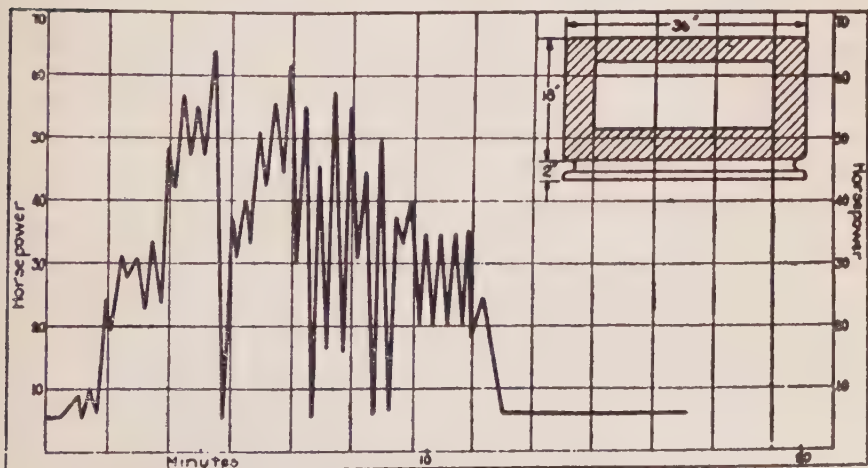


FIG. 64—THE GRINDING TIME IS REDUCED BY RECESSING THE SURFACE

including great wheel economy, cool grinding, easy admission and emission of coolant, and convenient handling of abrasive, both in and out of the machine. Segment wheels have been in use for more than ten years. They have been supplied in several forms, all of which have aided in the development of present types.

Chip action as developed by a segment wheel is shown in Fig. 62. In this illustration, *A*, *B*, *C*, and *D*, are the same as shown in Fig. 61, while *E*, *F*, *G*, and *H*, are a repetition of *A*, *B*, *C*, and *D*. With a segmental wheel, however, the recess enables the crumpled chips to be forced out of the way, both by grinding action and the cooling solution, so that the pressure between the wheel and the work is reduced materially. While the recesses in the wheel face afford chip space, their most valuable function is to permit a passage of the cooling solution to wash away the chips.

A typical grinding problem is to produce in the matter of a few minutes, after planing or milling, a flat surface 52 inches wide, 144 inches long, no portion of which is to be more than 0.0025-inch below any other portion. Such an operation can be performed readily on a surface grinding machine. Fig. 63 shows the horsepower required to grind a flat surface 36 inches long and 18 inches wide. The grinding time was 20 minutes and 80 horsepower was required. By recessing the part as shown in Fig. 64, a little less than 60 horsepower was required, while the grinding time was reduced nearly 50 per cent. These illustrations show graphically why recessed surfaces should be provided when possible.

THREAD GRINDING

Grinding is followed to quite an extent in producing very accurate screw threads on gages, hobs, etc. The practice also is followed in production work to some extent, such as finishing worms for automobile steerers. Not all forms of threads can be finished by grinding. For example, a true V-thread would be hard to produce due to the fact that the grinding wheel could not be trued to the theoretically fine apex necessary. Again, a Whitworth form thread would present difficulties as also would a square thread. Forms most adaptable for finishing by grind-

ing are those with flat tops and bottoms such as the United States standard and various worm threads such as the acme.

A thread-grinding appliance must be equipped with a very accurate lead screw, for the finished thread cannot be more accurate than the master used in producing it. Elastic-bond wheels generally are used for thread grinding as they hold their shape well. They are operated at a peripheral travel of about 5000 feet per minute while the work speed seldom exceeds 20 feet per minute. The wet grinding process should be used whenever possible. The amount to leave for grinding depends entirely on the size and shape of the piece. Thus a short "chunky" thread gage can be finished with a minimum allowance. A larger piece that has been heat treated would require a liberal allowance as three factors would have to be considered: the accuracy of the screw used in roughing out the work in the soft state, the warping of the piece in hardening and the longitudinal shrinkage of the stock. Experience is the only guide to follow in determining the finish allowance.

THREAD-CHASER GRINDING

Thread chasers should be ground preferably on machines provided for the purpose. If equipment of this kind is not available, the toolmaker must exercise his ingenuity in setting up a small universal grinder for the operation. Proper lead clearance is of the utmost importance. Care should be exercised to have the throat clearance just sufficient to impart a good cutting edge. Too much clearance will weaken the die. In using any of the dies on the market at the present time it is well to get the manufacturer's recommendations as to grinding clearances.

TOOL GRINDING

Left to their own initiative, mechanics grind tools to suit their individual tastes, to a great extent and while clearance angles have been established for various cutting tools such as used on lathes, planers, slotters, etc., no two men will grind the angles alike when following hand grinding methods. Hand grinding also is to be discouraged in the majority of instances as it results in a maximum amount of lost time.

A better plan is to install a semiautomatic tool grinding machine in the tool crib so that one of the tool-crib boys can keep up the stock of sharp tools in his spare moments. Thus the ma-

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chine operators can exchange dull tools for sharp ones. Such tool grinding machines are equipped with adjustments for generating the desired clearance angles on all kinds of tools. Charts are provided with them giving the correct angular setting for each cut. The angles were determined through careful research and

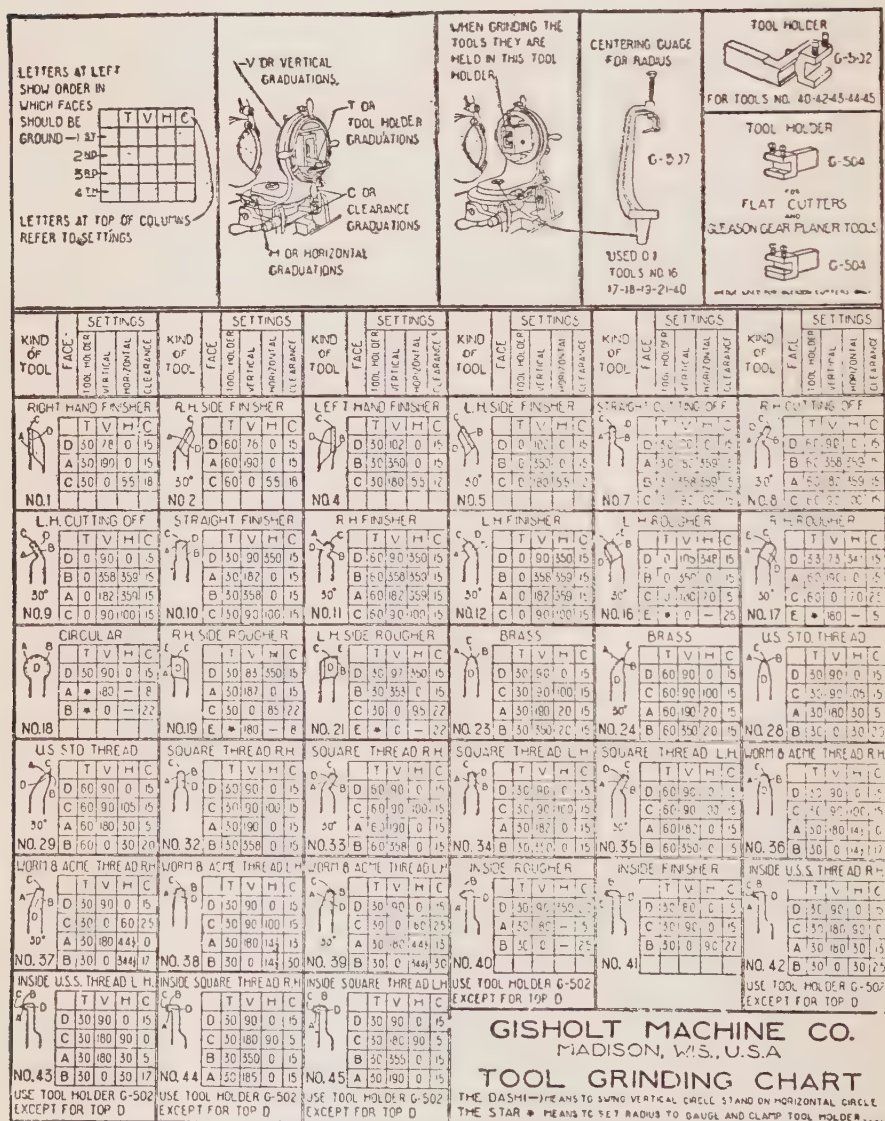


FIG. 65—ANGULAR SETTINGS FOR VARIOUS TOOL GRINDING OPERATIONS

experimentation and the general use of the practice is sure to result in economy. Such a chart is simple to understand. The one shown in Fig. 65 was compiled by the Gisholt Machine Co. Let it be assumed that it is necessary to grind the right-hand finishing side tool that is shown at the top of the left-hand column. The faces requiring grinding are marked *A*, *C* and *D*. The instruction panel carries the letters, *D*, *A* and *C*, at the left and at the top the letters, *T*, *V*, *H*, *C*. To grind the surface, *D*, the adjustments, *T*, *V*, *H*, *C*, are set at 30, 78, 0 and 15 degrees, respectively. The second illustration at the top of the chart shows the operator where to make the necessary adjustments.

TRACK GRINDING

Some five or six grades of rails are used by traction companies, some being higher in carbon than others, and the grit and grade of the abrasive and the method of its application vary according to the work in hand, according to K. H. Lansing. Much of the rail material used is hard, open-hearth steel. Manganese steel possessing great wear-resisting properties, is largely used for frogs and switches. High-manganese steel welding rods seem to have solved the problem of making successful repairs on manganese special work for tracks.

Both the reciprocating and the rotary methods of grinding are applied to street railway tracks. With the exception of some types of reciprocating grinding, no water is used and the grinding wheels run dry. In reciprocating grinding, where abrasive blocks instead of wheels are used, water is piped from the machine so that it flows between the abrasive and the work, keeping the grinding surface cool and promoting free cutting. Experience has shown that reciprocating grinding removes the minimum of metal in attaining a smooth, tractive surface. The rotary method may be employed for snagging rough surfaces and high spots and for making a fairly smooth finish.

Twenty years have been required to develop the most improved models of track-grinding machines and there is a wide variation in their design. Numerous adaptations and make-shift devices of local construction from time to time appear in use on the street railways, but these ordinarily are employed merely to fill in, until the delivery of a machine of standard make.

In grinding tracks, care must be taken not to use a wheel or block that is too spongy, too fine, or too dense. Manufactured alumina wheels or blocks in vitrified bond are suited to this work. The blocks used in reciprocating grinders should have a relatively soft bond.

The Philadelphia Rapid Transit Co., Philadelphia, and the Public Service Railway Co., Camden, N. J., are extensive users of track-grinding equipment. Both companies use rails of medium hardness. Neither company ever permits track corrugations to accumulate. The Philadelphia Rapid Transit Co. operates reciprocating, rotary, and portable telescope-shaft grinders. The Public Service Railway Co. on its Camden division, uses reciprocating and rotary grinders. The Boston Elevated Railway Co., Boston, is using 24 reciprocating track-grinders of a new type. This grinder has two aluminum oxide bricks, each 10 x 4 x 2½ inches and usually of 16 grit, M grade, although the grit may be anywhere from 12 to 20, according to the work. These machines operate at the rate of 340 strokes to the minute and are employed largely to grind new joints.

The ordinary reciprocating track grinder, which is of a simple type with the automatic features of some grinders eliminated, is a safe one to place in the hands of ordinary labor without fear of damage to the rails. It is operated with a 3½ horsepower motor, and the power is transmitted to the reciprocating head through an ordinary crankshaft and connecting rod. The transmission is by silent chain drive, direct from motor shaft to crankshaft. The abrasive used is in the form of four aluminum oxide bricks, usually 16 grit, P grade, although the grit may be within the range of 12 to 20.

Each block is 10 x 4 x 2½ inches, affording a grinding surface 17½ inches long and 2½ inches wide and each has a steel pin inserted in one end. The blocks are placed endwise in the cross head, or block holder, which slides bodily in guides. The stroke is 5½ inches at a speed of 370 strokes per minute. As the blocks wear down, the end wedge is slackened with a small hand wheel and the blocks are fed downward by means of a larger hand wheel operating the feed screw through a compression spring. The grinding surface is long and straight so that the grinding elements cannot fall into a low spot.

By turning a hand crank, which shifts the two 12-inch track

wheels sufficiently to cover the rail with the abrasive blocks, the machine may be operated on short radius curves. There is an outrigger equipped with track wheels for the mate rail. The outrigger is detachable for convenience in hauling or storage. The time consumed is approximately 40 seconds from cessation to resumption of grinding. This machine is used on joints, corrugations and special work and can easily cover 250 to 350 feet of grinding surface in a day's time.

While rotary grinders generally are used for taking off rough spots and similar coarse work, the reciprocating machine is used more especially for finishing. The latter is derailed through a hoisting gear operated by a hand crank and two derail or transporting wheels, each 4 feet in diameter. The operator turns the hand crank in one direction to hoist the machine onto the transporting wheels and turns it in the reverse direction to lower the machine to the track.

To start the reciprocating machine, the operator attaches the end of the wire from the trolley pole to the terminal on the switchboard, first passing the wire through a hole in the switchboard housing. The machine is placed over the rail to be ground, and is lowered to the rails in the manner previously described. Water is supplied to the abrasive blocks from a tank carried on the machine. Care should be taken to have the abrasive free from the tracks when the machine is started.

In grinding corrugations, the rail is traversed a short distance, which plainly shows each corrugation distinctly. At frequent intervals the machine is pushed ahead so that the rail being ground may be examined, it being necessary to continue grinding until each dark spot disappears. In grinding joints the operator makes the cut across the depression and nicely tapers the extreme ends of the cut to meet the original rail-head surface. New joints are leveled by light cutting directly over them. Water is used freely in all these operations, care being taken to keep the holes in the water pipe clear.

The rotary track grinder is used extensively for removing surplus metal after a low joint has been built up by arc-welding and for grinding cupped or pounded rail ends at the joint. It is driven by a 5-horsepower motor which is directly connected to the grinding wheel. This wheel is mounted on a sliding carriage which is moved backward and forward in guides over the

rail to be ground, by means of a large hand wheel in front of the operator. The motor is mounted on a hinged plate and the belt may be tightened by adjusting one bolt. Two small hand wheels are provided at either end of the machine for feeding the grinding wheel to the rail to compensate for the wear of the abrasive wheel. There are levers under each hand wheel for quickly raising the grinding wheel before derailing the machine. Derailing is accomplished through the operator turning the hand crank at the end of the machine, thus lowering the derail wheels to the pavement and raising the heavy end of the machine from the track. Ninety per cent of the weight of the machine is suspended over the derail wheels and the operator can easily raise the outrigger end of the device and pull it off the track as a trolley car approaches, or when he is through with his work. The derail wheels are 30 inches in diameter and the machine can be trailed behind a truck.

An important feature of this machine is a simple adjustment whereby the grinding wheel may be tilted to any desired angle, thus eliminating constant hand-dressing of the wheel which otherwise would be necessary to avoid changing the angle or contour of the rail head.

The grinding wheel has an outboard bearing which tends to prevent wheel-chatter and the tendency of the wheel to grind cups in the rail. The outboard bearing has bronze bushings on a three-point suspension to take up wear. The grinding wheel, as a unit with the motor, travels forward and backward over the rail, while the machine is locked stationary on the track. The abrasive wheel used ordinarily is aluminum oxide 14 inches in diameter, 2½-inch face, 16 grit, P grade. It is driven at the speed of 1750 revolutions per minute.

The grinding operation is as follows: After the machine has been placed on the track, the end of the wire on the trolley pole is attached to the terminal post on the switchboard and the trolley pole is suspended from the overhead trolley wire. The two small hand wheels at either end of the machine raise or lower the grinding wheel at the end of the run. The operator must be careful to have the abrasive wheel clear of the track when the machine is started. Before starting to grind, he moves the carriage backward and forward by means of the large hand wheel until the abrasive wheel touches the rail at both ends of the run. He is careful to avoid chipping the grinding wheel when de-

railing, using the lever under the two small hand wheels to lift the abrasive wheel clear of the track. When replacing the machine on the track, the operator notes that the levers are thrown back into place before he resumes grinding. The grinding carriage is moved slowly backward and forward over the rail by turning the large hand wheel in front of the operator. At both ends of the guides on which the grinding wheel carriage travels, there are adjustment bolts for raising the guides at each end, permitting the grinding wheel to run off to a gradual taper, at the end of the stroke, instead of grinding the rail-head to a shoulder. When it is necessary to dress the grinding wheel, the hand dresser is inserted in a bracket under the machine.

The portable telescope-shaft grinder is a variation of portable track-grinder having a flexible shaft. This is a small, light grinder, which is simple in construction and easily moved about. It has square tubing and a square telescopic shaft. There are two universal joints at each end of the shaft and the machine is equipped with a derail, or transporting wheel on one side. The operator merely pulls the head of the machine around when a trolley car is about to pass.

The operator, in grinding, holds the machine by a long handle and can draw it back and forth after the manner of a lawn mower. It is equipped with a 3-horsepower motor mounted on a separate carriage which remains off the track. It is used on open-hearth steel tracks for pick-up work, for roughing off joints just welded, and for grinding frogs and switches. An aluminum oxide wheel 10 inches in diameter, 1-inch face, 16 grit, P grade is used and ordinarily it is revolved at 1300 revolutions per minute.

A type of portable swing-frame grinder equipped with a movable swing-frame and arms and a ball-bearing head in an upright pedestal is also used for track grinding. The arms can swing backward and forward, so the operator can readily move the wheel over the rail. The grinding wheel can be turned completely around, making it easy to grind in the groove, or on the back of the rail at any desired angle. A lock-pin on the grinding wheel head, directly within reach of the operator, is the only adjustment needed for turning the grinding wheel to any angle. All the moving parts of this grinder, except the lower half of the abrasive wheel are entirely enclosed. The steel bevel gears

run in an oil-tight gear case packed with transmission grease. All the hand movements of the operator are lightly and easily performed and only slight effort is required to exert the necessary wheel pressure against the rail in grinding. To derail the machine, the operator simply pulls the head around so that the grinding wheel is off the track. This machine is used for removing surplus metal after building up low joints and special work by arc-welding. The wheel used is aluminum oxide, 12 inches in diameter, 1½-inch face, 20 grit, P grade, operated at 1750 revolutions per minute.

VALVE GRINDING

Automobile-engine valves should be ground in their seats occasionally. Otherwise they are not gas-tight which results in a lack of power. An excellent medium for grinding in the valves is No. 120 carbide of silicon. A number of valve grinding compounds, however, are on the market the basis of which is carbide of silicon. The use of these compounds saves the necessity of mixing the granular material with oil.

If the valve seats are worn or pitted deeply, it may be necessary to recondition them with a valve facing tool. The valves also can be refaced at slight expense by taking them to an automotive engine repair shop equipped with a grinder for this purpose. In cases where the valve stems are burned to a depth of more than 1/16-inch on the diameter new valves should be fitted. These are not expensive. A burned valve stem is liable to break and if the engine happens to be of the overhead valve type, the broken valve will fall into the cylinder where it is liable to punch a hole through the piston head, spring the connecting rod or crankshaft, or cause other trouble. Thus new valves are cheapest in the long run.

A number of appliances are on the market for valve grinding. They all embody means for turning the valve in its seat. Some of these devices are efficient—others are useless. The expert who understands the business gets along very well with a screw driver. Many inexperienced motorists make a mistake in applying too much pressure during the valve grinding operation. This does not give the abrasive a chance to cut.

After the head has been removed, the valves should be taken out and washed in gasoline. Then starting with No. 1

valve (the valves are numbered, or they should be) apply a small amount of carbide of silicon and oil to the valve and set it in its seat. Twist it back and forth with a rotary motion by means of a screwdriver or other appliance, lifting the valve occasionally to give the abrasive a chance to spread over the seat. Continue this operation as long as the abrasive can be heard to cut. As soon as it ceases *scratching* lift the valve out, clean it and its seat with gasoline, apply some more abrasive and continue the operation until a good even bearing results. This should show a dull finish with no carbon pits.

Great care must be exercised in wiping out the seat for if a slight amount of carbide of silicon is permitted to work into the cylinder it will wear the walls and later it may work into the main bearings through the lubricating system. The results will be disastrous, to say the least.

In automobile manufacturing plants, the valves of motors are ground in their seats with No. 120 carbide of silicon grain, mixed with oil. Usually the operation is performed under a special machine designed for the purpose. Such a machine has a number of spindles, eight or twelve, depending on whether four or six-cylinder motors are made. These spindles have a reciprocating movement which imparts a little more than one turn to the valve. Connection between the spindles and the valves is made by a suitable driver. In the grinding operation, springs are placed under the valves so that as the spindles are automatically raised at frequent intervals, the grain and oil has a chance to spread over the work, thus affording a better cutting action. The valve in one motor can be ground in place in about one and one half minutes.

The throttle valves of locomotives are ground in place with carbide of silicon. Such valves are of the semi-balanced type so that two seats must be ground. No. 60 grit material is used mixed with oil followed by grinding with Nos. 80 and 120 grit. Usually the valve is turned in its seat by hand by means of a wooden lever clamped in place by a bolt through the spindle hole.

Brass cocks are ground in their seats. Formerly powdered glass mixed with oil was used, but today artificial abrasives are employed generally. Usually an appliance is used that locates a number of cocks at once so that several can be ground

simultaneously. Where one cock only is to be ground, a repair job for example, it can be ground in by hand readily with carbide of silicon, emery, powdered glass, garnet or quartz.

WOBBLE WHEEL GRINDING

A wobble wheel, so-called, is one mounted between angular flanges so that its sides are set at an angle as shown in Fig. 66.

Such wheels have been used with considerable success, especially on certain classes of surface grinding. Due to its peculiar manner of mounting, a wheel of this kind operates over the work with a shearing cut which is said to be productive of

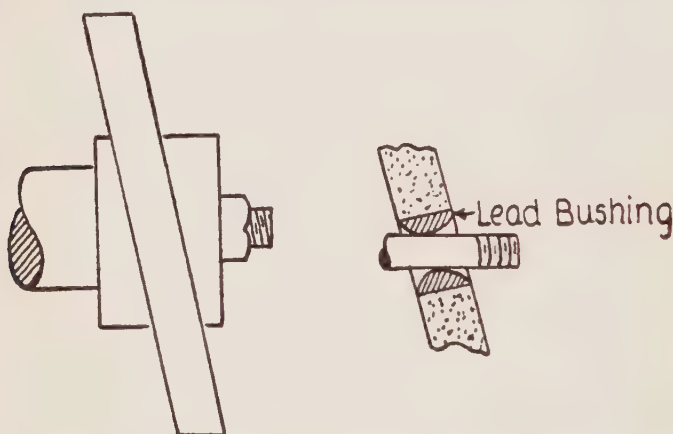


FIG. 66—WOBBLE WHEEL FOR SURFACE GRINDING OPERATIONS

excellent results. As the illustration shows, the wheel flanges are tapered on the inside. In mounting a wheel in this manner the hole in the lead bushing must be enlarged as shown at the right so that it will fit freely over the spindle without setting up a side strain as the spindle nut is set up. Even a slight side strain would break the wheel. The flanges should be recessed on the inside as in regular practice. After the wheel is mounted it is, of course, necessary to true off its periphery to bring it parallel with the spindle axis.

SECTION IX

GRINDING WHEELS

In the following pages will be found data pertaining to the manufacture and use of grinding wheels arranged in alphabetical order as follows:

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Economy of Large Wheels	292	Skillet Wheels	354
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Grinding Wheel Industry	293	Testing Wheels for Efficiency	356
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Grinding Wheel Standards	300	Wear of Grinding Wheels	359
Grinding Wheel Trade Names	313	Weights of Grinding Wheels	361
Grits, Grades, and Bonds	315	Wheel-Operating Suggestions	361
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Grinding wheels used in foundry cleaning rooms possess possibilities of increased production as do tools in any other part of the factory, according to C. C. Hermann. However, to learn that a given wheel has a low production rate and another one a high one we must have reliable means of comparison. With this idea in mind the grinding wheel record card shown in the accompanying illustration was made. The wheel data is placed at the top of the card and the production of the wheel in the spaces below. The card is self-explanatory.

The method of collecting the data is comparatively simple. The workman keeps track of the number of times he trues the wheel by marking the dressing on a slate hung near his wheel.

Name of Wheel.....Dia.....Thickness.....Grade.....Grain.....

Date on _____ Date off _____ Dia. of wheel removed _____

WHEEL PRODUCTION

[illegible]

CARD FOR COMPILING GRINDING WHEEL DATA

The amount earned by a workman is obtained directly from his time card. In many shops the workers have a piece rate; in which case the earnings will be greater than the number of hours multiplied by the hourly rate. The piece work system, in this regard, provides a more accurate check on production than a day rate system. The men are not apt to kill time when engaged in piece work and the foreman keeps more accurate check on the time at the wheel generally. However, either system can be used in checking production, the variation being confined to the accuracy of keeping time.

Such records possess a three-fold purpose. From the purchasing standpoint they give an idea relative to the efficiency of different makes of wheels of the same grade and grain. Selecting at random two different makes of wheels on which the production in pounds of castings were checked up carefully the following variation was noted. On one wheel, the amount of metal ground from the castings per pound of abrasive removed from the wheel was 28, while on another wheel of the same grade and grain, but of different make, only 23 pounds of metal was removed. The difference of five pounds of metal per pound of abrasive is a considerable one and worth taking into consideration. The continued collection of the necessary data to check the wheels on the pound basis would require considerable clerical time. The wheels would necessarily be weighed when put on the arbor and when taken off and their diameter would be measured. The castings produced by the wheel per day must be weighed. The calculations must be made. This check is valuable once in a while, but the amount earned by the workman and the number of times the wheel is dressed will provide a reliable index.

Another fact disclosed by the record is the relative efficiency of different grade and grain wheels for the work. Comparing different wheels, we find considerable variation in production. This may be due to the speed of the wheel, or it may be due to the class of work handled. A heavy casting will be harder on the wheel and thus cause increased wear over that of a light casting. This is because the workman believes that he must bear harder with the heavy casting than with the light one. Mass has its effect on the workman's interest. A soft wheel operated at a high peripheral speed will act like a hard wheel

at a correspondingly lower speed. Conversely a hard wheel operated at a low speed will act like a soft wheel operated at a high speed. Arbor speed should be standardized in two stages, that is, the provision of a higher speed after the wheel has worn down somewhat. This keeps the wheel working at its highest efficiency. In some shops this condition is obtained by changing the wheel from one arbor to another while in others the step pulley is used.

The record also discloses the relative ability of the workmen and the degree of supervision. Some workers will save their wheel at the expense of production while others will simply dress the wheel away. Wheel dressers should be kept out of the hands of the inexperienced man. He often will cut away three or four times the amount of abrasive actually necessary. The foreman should, for the first few days at least, do the dressing for a new man. The new employe should be instructed in the right and wrong way to true a wheel. He should be shown that the dull grains lay right on the surface of the wheel and that just under these are the sharp ones. He should be made to understand that the dressing of the wheel is what wears it away principally.

The wheel may also be worn away rapidly due to the method adopted by the man in applying his work. If the wheel is worn in ridges, the high spots must be trimmed away. This necessitates the removal of abrasive that has done no work whatever. The workman should be taught to keep the face of his wheel as nearly square as possible. Maximum production per wheel will result.

CUTOFF WHEELS

These are elastic-bond wheels, very thin in proportion to their diameter. They are used for cutting off materials such as high-speed steel; fabricated metal sections, such as automobile windshield frames, foundry cores, etc. Their value lies in the fact that they leave a clean kerf without raising heavy burrs. Again they can be used for cutting fragile materials that cannot be gripped firmly in holding fixtures. Shellac, rubber and bakelite bonds are used in making these wheels. Popular sizes are 10 to 12 inches diameter and $\frac{1}{8}$ -inch thick. They should be operated at high speeds to show

efficiency. The rubber-bond wheel can be operated safely at a peripheral speed of 12,000 feet per minute. They generally are used on a pedestal-type grinder fitted with a swinging rest for locating the work.

BALANCING GRINDING WHEELS

The importance of correctly balanced grinding wheels cannot be overestimated, for when a wheel is out of balance it causes vibration which may cause it to fracture. Again, if a wheel on a precision grinding machine is out of balance, accurate work cannot be assured. Grinding wheels, above certain small diameters at least, are put in static balance at the plant of the grinding wheel manufacturer.

Because a wheel is in balance when it leaves the grinding wheel factory, it is no sign that it will remain so as it wears away. There are several methods followed in balancing grinding wheels. One is to chip away material from one side near the periphery, the heavy side, of course, being chipped. This is not always a satisfactory method as an inexperienced man may break the wheel. Another method is to use the so-called balancing flanges which are flanges provided with heavy sides. They are turned until the heavy side compensates for the light side of the grinding wheel.

Wheels for precision grinding machines are balanced in several ways. Landis grinding machines have wheel holders fitted with balancing blocks which are weights fastened in an annular groove. Thus by changing the relative position of the weights, the wheel can be brought in balance. In many cases lead is staked in between the holder and the countersunk shoulder to compensate for the heavy side. Grinding wheels always are balanced statically. Why comparatively wide wheels are not balanced dynamically is hard to state. Possibly machines that can be adapted for this use may be developed as the art of grinding progresses.

BUSHING CHUCK

A device for locating a grinding wheel while the lead bushing is being poured in place. Bushing chucks are of various types, but they all embody means for locating the wheel centrally

while a number of arbors of different sizes are provided for casting bushings with various size holes. Bushing chucks form part of the equipment of the grinding wheel factory, while also they are found in agencies where large numbers of wheels are handled, in which case it often is necessary to change the size of the hole to suit the needs of customers. Where a very large number of wheels are consumed, it might prove economical for the user to buy wheels without lead bushings, bushing them to suit local requirements. Thus where grinding wheel stands with varying size arbors are installed one size of wheel might be made to fit one of several machines. The same result, however, can be attained by buying wheels with holes to fit the largest size of spindle and bushing the wheels with wood bushings (which can be had from any grinding wheel manufacturer) to fit the smaller spindles.

ECONOMY OF LARGE WHEELS

In the selection of grinding machinery it is practicable to purchase machines that will accommodate large wheels. This pertains to machines for off-hand grinding for in considering precision operations, the size of the work determines the machine size, which in turn influences the diameter and width of the wheel.

With machines for off-hand grinding, however, such operations as snagging castings and forgings, economy is shown by using large wheels. A large wheel has more abrasive cutting points on its periphery than a small one; thus it will operate for a longer time without requiring dressing. Again, the price of grinding wheels per pound, or per cubic inch, decreases with the larger sizes. This can be proven readily by referring to any standard grinding wheel price list as furnished in grinding wheel catalogs. All that is necessary is to compute the cubical contents in cubic inches of wheels, say 10 x 2 inches 14 x 2 inches, 16 x 2 inches, 18 x 3 inches, 24 x 4 inches, 30 x 4 inches and it will be found that the larger wheels are the cheapest.

Further, the use of comparatively large wheels does not result in an undue accumulation of wheel stubs which have little value. The less the number of wheels used, the smaller the stub pile per annum. The production engineer and the

purchasing agent will do well to investigate this subject thoroughly. In many cases, where a large number of wheels are used annually for rough grinding, it will pay to discard grinders capable of accommodating wheels say 14, 16 or 18 inches in diameter and installing heavy-duty grinders that will carry 24, 30 or 36-inch wheels.

FILLED WHEELS

In a filled wheel, the spaces between the abrasive grains are filled with a material such as oil, wax or resin. Such wheels are especially adapted for grinding materials that have a tendency to load the wheel. In this category are aluminum, copper, brass, etc. Many years ago it was common practice to place a wheel to be used for aluminum grinding in a tub of oil where it remained overnight. The next morning the wheel was mounted and as soon as the superfluous oil had been thrown off by centrifugal action, the wheel was ready for use. This method, while it brought about the desired end, was costly and untidy. Experimentation led grinding wheel manufacturers to adopt various fillers as previously mentioned.

GRINDING WHEEL INDUSTRY

The following data on the grinding wheel industry were prepared by the late Henry Richardson and delivered at a meeting of the Grinding Wheel Manufacturers' Association of the United States and Canada. Mr. Richardson pointed out that he did not intend to go into deep details, but that his purpose was to sketch the origin and growth of the various abrasive processes.

Grinding wheels are made by four principal processes called the elastic, silicate, and rubber or vulcanite. There have been other processes employed since the beginning of the manufacture of solid wheels, but none of them are now employed to any great extent. Some time prior to 1867, the New York Belting & Packing Co. made the first solid grinding wheel, employing in its manufacture the vulcanizing rubber bond. At the start these wheels were sold without being trued or fitted in any way, the consumer bushing the hole to reduce its size, or enlarging the hole with a red-hot iron. This process, now greatly refined to be sure, is at present in use by a few grinding wheel manufacturers.

Probably the first departure from the rubber wheel was the Northampton Emery Wheel Co.'s product, in which a binder of glue and cement was used as early as 1867. These wheels were made without heat, and required a long drying time in their manufacture. Moreover, thick wheels had to be built up by rubbing and gluing together thinner wheels. Necessarily the process was a long one, and with the idea of a reduction of the time, a binder of oil and japan was perfected shortly after which was used by the Northampton company up to the time of its disorganization in 1910, when trouble with the quality of raw materials available caused it to discontinue operations.

The first traveling salesman for the Northampton company was Harland P. Hyde, later connected with the Waltham Emery Wheel Co. as my partner, and it is interesting to recall that he carried a sample line of wheels of different sizes and grain with bushings to adapt them to the arbors on which he hoped to place the wheels. It is perhaps a long step from Mr. Hyde's methods to the salesman's methods of today, but it is to such men as he that the present size of the grinding wheel industry can be attributed. General Otis will be recalled as the treasurer and general manager of the Northampton company at its inception and until his death in 1894.

About 1872, in Detroit, Mich., there was an ex-captain of sharpshooters of the famous Bergan regiment, a Yankee from Wallingford, Vt., Gilbert Hart by name. He was employed by a manufacturer of artificial stone window sills, who used a bond composed of silicate of soda and an earth clay, which when mixed with lake sand, dried, baked and chemically treated with a bath known as "bittern water" resulted in a close approximation of natural sandstone. Mr. Hart was blessed with the idea that this process could be used to make a solid emery wheel. Luckily the plant across the street from the stone company's shop was a safe plant (no pun intended) and it was here that Mr. Hart's first wheel, not trued or tested, was tried out. The report, to quote literally was as follows: "On the opposite end of the grinder was a Northampton wheel—and although the silicate wheel was only an experiment, strange to say it compared very favorably with the Northampton product, and remained on the grinder until worn out." This report

was somewhat different from the one that a salesman received when he called to see how a lot of silicate wheels that he had previously sold were working out. He was told that they were working fine, the men were using them in place of soap for washing their hands.

The first regular sale of wheels was made to the Detroit Stove Works, and consisted of a dozen wheels, 12 x 2, at \$14.05 each, net, a price comparing approximately with 16 per cent discount from the present price list. In 1878, one of Mr. Hart's wheels burst in the grinding room of a brass foundry in Detroit and killed the son of the proprietor, one of Mr. Hart's most intimate friends. This accident led to the first step along safety lines as applied to grinding wheels, and on March 26, 1878, Mr. Hart was granted a patent on a wire web inserted in wheels to give them added strength. It is recorded that Mr. Hart's discovery of the idea of the wire web saved a valuable man for the grinding wheel industry, for without some such device he would undoubtedly have given up the manufacture of a product, as he puts it, so dangerous to human life.

Vitrified wheels were without doubt first made by the Vitrified Wheel Co. in 1872 on two patents issued in 1864 and 1866, although the Vitrified company catalog makes the modest claim that it is *one* of the oldest concerns in the country making wheels by the vitrifying process. As a matter of fact, it still has one employe who has been connected with the concern since 1873. Further patents or copyrights were granted the Vitrified company in 1875 and 1877. In 1879 this concern was reorganized and moved to Westfield, Mass., where it has continued business to date, using the vitrified process exclusively up to 1893, when the silicate and japan processes were added, the latter being discontinued in 1906. In 1905 an entire new plant was built with subsequent additions until it reached its present size.

Although the Norton Co. was not incorporated until June 2, 1885, the business really received its start as early as 1873, or shortly afterward, when in a little pottery factory in Massachusetts, owned by F. B. Norton, a solid emery wheel, the bond of which was clay, was made in a pottery kiln. This company has forged ahead in the industry through the efforts of its originators and today it is the largest grinding wheel concern

in the world. The Norton Co.'s most original contributions to the grinding wheel industry have been along the lines of abrasives which will be touched upon later.

The elastic process, or as it was originally known, the Richardson elastic process, was originated by myself, then in the employ of the American Watch Tool Co., in an effort to produce an article specially adapted to the finer classes of work, principally in watch tool making. The first wheel was made on the top of my mother's kitchen range, and the process consisted of spreading out the mixture of shellac and emery on the hot stove and then roughly forming the cooled wheel into an approximately round shape by means of a pair of pliers. There were gradual steps to the present product concerning which I will not go into detail.

Surely as important as the origin of the various processes which we employ, has been the development of abrasive grain, the meat of the nut in the grinding wheel industry. Many remember the old days of Turkish emery, Georgia and North Carolina corundum, Canada corundum, Naxos emery, etc. in turn, but it was not until about 1901 that the natural aluminous abrasives were supplemented by an electric furnace product originally made under patents controlled by the Norton Co. and called alundum. It is aluminum oxide in crystal form and results from an electric furnace treatment principally of bauxite. It is pre-eminently an abrasive for materials of high tensile strength and its manufacture now by the Norton Co. as alundum and by a number of other concerns under other names has assumed large proportions. Virtually these abrasives are improvements on nature.

Unlike such materials and having no counterpart in nature is carborundum, a chemical compound, silicon carbide, another electric furnace product with raw materials of pure silica sand and high-grade coke with small quantities of sawdust and salt to facilitate the reactions. This material was first created by Edward G. Acheson in 1891 when he discovered a few bright blue crystals surrounding the carbon electrode in an iron bowl in which he had fused by means of an electric current a mixture containing carbon and silicon. The first operations of the Carborundum Co. were at Monongahela City, Pa., in October, 1891. In 1893, small dentist's wheels were first

made and these met with such success that the field of applications was extended and in 1895, its present plant at Niagara Falls was started. Carborundum is pre-eminently a cast iron tool, but it is most efficient on materials of low tensile strength.

There have been but few startling new things in the grinding wheel industry in the past fifteen years. New concerns have started up, some short lived, others flourishing, but no new abrasives, no new processes, nothing but perfection of the things at hand has been done. True, we have made rapid progress along the lines of standardization and safeguarding appliances, and probably our most recent accomplishment is our present organization through which we have come to the adoption of a standard price list, a standard code of grinding wheel safety, standard shapes for abrasive wheels, uniform cost accounting methods and, above all, a realization that we all are here for the common good cause of building up an industry upon which today depends in part the safety and even the existence of these United States of ours.

GRINDING WHEEL MANUFACTURE

Grinding wheels are manufactured by four principal processes, namely the vitrified, silicate, shellac and rubber. Each type of bond possesses advantages for certain kinds of work and for the sake of convenience each method will be treated separately. The bonding ingredients in the vitrified wheel is a high grade of kaolin or potter's clay. The initial step consists of mixing the desired amount of bond and abrasive material. Two processes are followed, the puddling or wet method and the pressing or dry method. In rare instances wheels for specific purposes are put through both processes.

In making wheels by the pressed process the first step is to measure out the correct proportions of grain and bond to form a specific grade in the finished wheels. The ingredients then are tumbled in a barrel for several hours, a little water being added to the mix, just enough to cause the bond to surround each grain. Next this material is pressed in molds under immense hydraulic presses. The operator measures out a definite amount of material by weight. This is put in a cast iron mold and a cover put over it. The mold then is placed under the press ram. Over 5000 pounds pressure to the square inch is used in making some types of wheels.

The first step in working by the puddled process is to mix predetermined proportions of bonding material and grain with water in mechanical agitators. After the mixture has been puddled for a few hours it is drawn off into molds, somewhat larger than the desired size of the wheels. The molds are quite simple, generally being sheet metal lined with paper. The material must be dried thoroughly, and in the case of large wheels several days are required.

The next step in the manufacture of both pressed and puddled wheels is to shave them to size. This is accomplished by placing the material on a machine resembling a potter's lathe. The table carrying the wheel revolves while the cutting tool is held in a head which is provided with the vertical and horizontal movement. Thus the *green* wheel can be cut to the shape and dimensions desired. Special shapes, such as cylinders, cups recessed wheels, etc., require careful treatment as the workman must keep within certain limit specifications.

After shaving, the wheels are ready for the vitrifying process which is accomplished in kilns resembling potter's kilns. The wheels are loaded in fire clay containers called *sagers*, the sagers in turn being packed closely in the kilns. Considerable skill is necessary in distributing the sagers so that each will be subjected to the desired degree of heat. When the kiln is full the door is put in place and luted with fire clay. Then the fires are built and the kiln brought up to the desired heat, kept there for a definite period and allowed to cool gradually. Skill is required in this operation. If the kiln is kept too hot the wheels will be overburned which destroys the bond. Too low a heat results in under vitrified wheels. If the kiln is brought up to heat too rapidly the wheels will be cracked. Skill and experience are the only guide.

Kiln heats usually are tested with pyrometric cones which are inserted in test holes provided for the purpose. Of late years, however, the use of pyrometers for checking kiln heats is becoming common. After the kiln has cooled off for several days the door is removed and the wheels unloaded and taken to the sorting floor where they are arranged as to size grit and grade, etc. Also they are inspected for soundness by tapping them with a light hammer. Grits and grades are identified by markings made on the wheels while in the green state.

In the silicate process the bonding material is silicate of soda which is mixed with the grain and other ingredients in mechanical mixers. The material then is tamped in molds, usually by hand. This operation requires skill for an improperly tamped wheel is of little value. Mechanical means have been devised for tamping wheels, but many manufacturers claim that this method is not as productive of satisfactory results as the hand process. After tamping the wheels are baked for a period sufficient to set the bond. This operation is performed at a comparatively low heat, in a coal, gas or oil-fired furnace. Sometimes electrically heated furnaces are used.

The next step in manufacture of both vitrified and silicate wheels consists of facing the sides on wheel lathes. This is accomplished with conical cutters or star-wheel dressers. Next the wheel faces are trued. Then the lead bushings are poured in place, the wheel being located in a bushing chuck for this purpose. A speed test follows wherein the wheel is brought up to a speed sufficient to subject it to a greater stress than will be encountered on operation. This is performed in a department provided for the purpose. Heavy oak boxes surround the wheels to prevent fragments flying if a wheel should burst while the speed is registered by tachometers. Balancing follows. This is performed on balancing ways. Each wheel must be in balance within predetermined limits. Otherwise it is rejected. Subsequent operations consist of testing for grade with a hand testing tool generally, although a few machines have been devised for the purpose. The hand tool resembles a screwdriver. The tester digs into the wheel with a twisting movement of his wrist. He becomes expert at this operation and he can readily detect off grades. Next the wheels are given a general inspection and after pasting the labels and tags in place they are ready for shipment.

In the manufacture of shellac wheels, ground shellac is first baked and then reground. This material is mixed in carefully predetermined proportions with the grain and other ingredients which are pressed in heated molds. A further baking follows. This process is quite simple, although a number of technicalities are involved which must be observed closely to make an acceptable product.

The initial step in the manufacture of rubber-bond wheels

is to prepare the raw rubber, which is received in sheets about $\frac{1}{8}$ -inch thick. This material is put through smooth-face, cast-iron rolls about 18 inches in diameter arranged so that one roll travels faster than the other. Several sheets of raw rubber are fed into the mill at one time and permitted to adhere to the lower roll so that the separate sheets are formed into one mass. The rolls are hollow. At the beginning of the operation steam is fed to them to heat the rubber and afterward water to maintain the correct temperature. After the rubber has been rolled for about 30 minutes, it is cut and removed.

In the next operation the rubber is compounded; that is, the necessary ingredients to aid in vulcanizing are added. This is accomplished by feeding the rubber and the vulcanizing agents, the chief of which is sulphur between rolls. This operation does not differ materially from the former one of preparing the raw rubber. In the next operation the desired amount of abrasive grain is added and rolled into the rubber. The stock then is passed between calender rolls after which disks to form the desired diameters of wheels are cut out in a press.

Thin wheels are made directly from the sheet material but in making thick wheels a number of sheets are placed together between dies and squeezed together. The wheels now are ready to be vulcanized which is accomplished in steam heated cylindrical containers. Careful tests of each batch of wheels are made by making test blocks from each batch. These are tested for tensile strength. Remaining processes consist of pouring lead bushings in the wheels and truing them. Truing is accomplished with diamonds on special truing lathes.

GRINDING WHEEL STANDARDS

Grinding wheel standards as given here are the result of five years of effort on the part of the Grinding Wheel Manufacturers' Association of the United States and Canada. Below is a summary of what standardization has accomplished:

Type of wheel	Number of existing shapes	Possible stock	Reduced to	Reduced stock	Possible stock saving
Internal	289	578,000	95	190,000	388,000
Cylinder	45	90,000	26	52,000	38,000
Straight cups	11	4,400	5	2,000	2,400
Flaring cups	27	10,800	8	3,200	6,600
Dish wheels	38	30,400	9	7,200	23,200
Double cups	4	1,600	1	400	1,200
Total possible stock reduction by simplification 459,400 wheels.					

GRINDING WHEELS

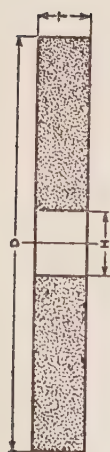
In the work of compiling the standards, thousands of wheel shapes were studied with the object of eliminating those for which there was little demand. The committee responsible for the standardizations was composed of George W. Chormann, chairman, the Carborundum Co.; W. L. Moore, the Norton Co., and L. Leslie Byers, the Abrasive Co.

In the interest of standarization and to enable the user to visualize at once the wide range of types of grinding wheels, there are shown on the following pages cross sections of the 14 standard types which are representative of practically all grinding wheels used on the standard makes of grinding machines. These types of wheels are numbered from 1 to 14 and each dimension designated by letter. The key to the dimension letters is shown below with the illustrations of the 14 standard types. This classification of grinding wheels greatly simplifies the stocking of wheels wherever a quantity is kept on hand. It also enables the user accurately to order a grinding wheel by giving the type number and the complete dimensions necessary to construct such a wheel, as designated by the cross section of that type.

KEY TO LETTER DIMENSIONS

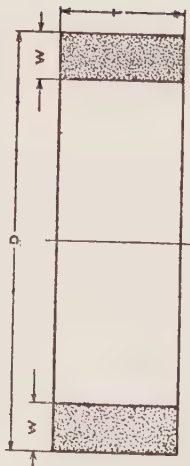
- A = Flat Spot of Bevelled Wall.
- C = Height of Dovetail.
- D = Diameter (Over All).
- E = Center or Back Thickness.
- F = Depth of Recess. (See Type 5).
- G = Depth of Recess. (See Types 5 and 7).
- H = Arbor Hole.
- J = Diameter of Flat or Small Diameter.
- K = Diameter of Flat Inside.
- M = Large Diameter of Bevel.
- N = Small Diameter of Bevel.
- P = Diameter of Recess.
- R = Radius.
- T = Thickness (Over All).
- U = Width of Face.
- V = Angle of Bevel.
- W = Thickness of Wall.

In the following pages are shown specifications of various standard grinding wheels.



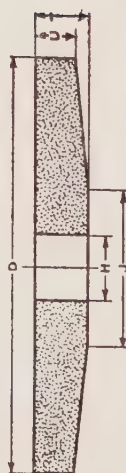
Type No. 1

Straight



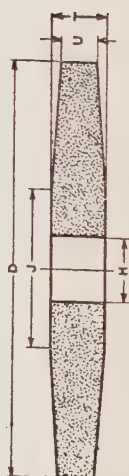
Type No. 2

Cylinder



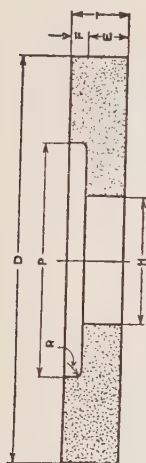
Type No. 3

Tapered One Side



Type No. 4

Tapered Two Sides



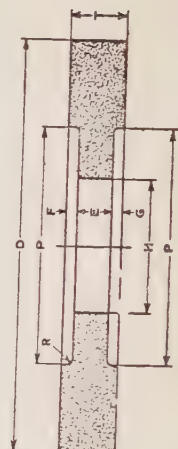
Type No. 5

Recessed One Side



Type No. 6

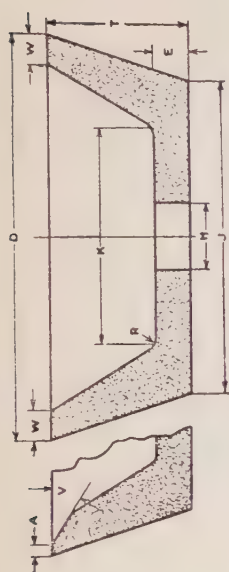
Straight Cup
Wheels of this type can be furnished with beveled face



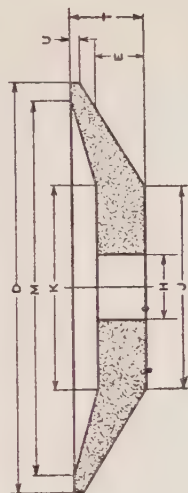
Type No. 7

Recessed Two Sides

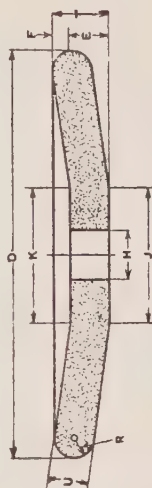
GRINDING WHEELS



Type No. 11
Flaring Cup
 Wheels of this type can be furnished with beveled face



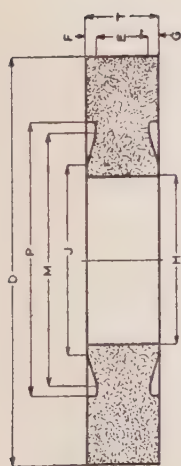
Type No. 12
Dish



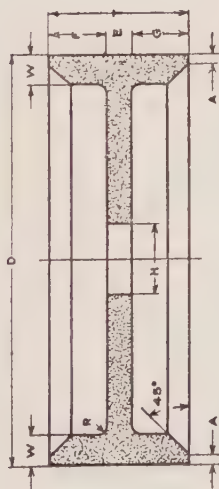
Type No. 13
(Saw Gummer) Sancer



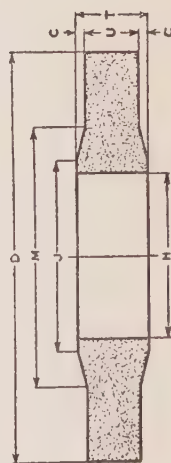
Type No. 14
Offset



Type No. 8
Countersunk Dovetail



Type No. 9
Double Cup



Type No. 10
Raised Dovetail

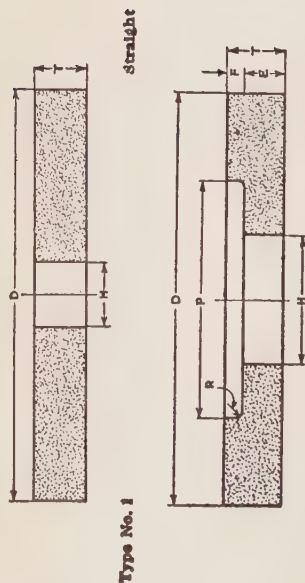
MINIMUM SIZES OF MACHINE SPINDLES

The following table gives standard spindle sizes for various diameters and widths of wheels. These data are important and no use of wheels should operate on any machine of given spindle diameter a wheel of larger diameter or greater thickness than herein specified.

Diameter Inches	Thickness of Wheel in Inches																			
	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	1	$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{3}{4}$	2	$2\frac{1}{4}$	$2\frac{1}{2}$	$2\frac{3}{4}$	3	$3\frac{1}{4}$	$3\frac{1}{2}$	4	$4\frac{1}{4}$	5	
6	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	1	1	1	
7	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	1	1	1	
8	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	1	$\frac{3}{4}$	1	$\frac{3}{4}$	1	1	1	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	
9	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	1	1	1	1	1	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	
10	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	1	$\frac{3}{4}$	$\frac{3}{4}$	1	1	1	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	
12	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	1	$\frac{3}{4}$	$\frac{3}{4}$	1	1	1	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	
14	$\frac{7}{8}$	$\frac{7}{8}$	$\frac{7}{8}$	$\frac{7}{8}$	$1\frac{1}{4}$	1	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	
16					$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	
18					$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	
20					$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	
24					$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	
26					$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	
30						$1\frac{3}{4}$	$1\frac{3}{4}$	$1\frac{3}{4}$	$1\frac{3}{4}$	$1\frac{3}{4}$	$1\frac{3}{4}$	$1\frac{3}{4}$	$1\frac{3}{4}$	$1\frac{3}{4}$	$1\frac{3}{4}$	$1\frac{3}{4}$	$1\frac{3}{4}$	$1\frac{3}{4}$	$1\frac{3}{4}$	
36						$1\frac{3}{4}$	$1\frac{3}{4}$	$1\frac{3}{4}$	$1\frac{3}{4}$	$1\frac{3}{4}$	$1\frac{3}{4}$	$1\frac{3}{4}$	$1\frac{3}{4}$	$1\frac{3}{4}$	$1\frac{3}{4}$	$1\frac{3}{4}$	$1\frac{3}{4}$	$1\frac{3}{4}$	$1\frac{3}{4}$	

STANDARD GRINDING WHEELS

Standard Wheels for INTERNAL GRINDING



Type	D	T	H*	Recess One Side		
				P	F	
1	$\frac{1}{4}$		$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$
1	$\frac{3}{8}$		$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$
5	$\frac{3}{8}$		$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$
1	$\frac{1}{2}$		$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$
1	$\frac{1}{2}$		$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$
5	$\frac{1}{2}$		$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$
1	$\frac{1}{2}$		$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$
1	$\frac{1}{2}$		$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$
5	$\frac{1}{2}$		$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$
1	$\frac{1}{2}$		$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$
1	$\frac{1}{2}$		$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$
5	$\frac{1}{2}$		$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$
1	$\frac{1}{2}$		$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$
1	$\frac{1}{2}$		$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$

*Arbors are sizes now in use.

GRINDING WHEELS

Type	D	T	H*	Recess	
				P	F
5	2 3/4		7/8	1 1/4	3/8
5	2 3/4	1	7/8	1 1/4	9/8
5	3		7/8	1 1/4	1 1/4
5	3	3/4	7/8	1 1/4	1 1/2
5	3		7/8	2 1/8	5/8
5	3 1/2	3/4	7/8	1 1/4	3/4
5	3 1/2		7/8	1 3/4	5/8
5	3 1/2		7/8	1 3/4	5/8
5	4	3/4	7/8	1 3/4	1 1/4

*Arbors are sizes now in use.

Internal Grinding Wheel Standards for NEW INSTALLATIONS

Wheel Diameter	Arbor	Wheel Diameter	Arbor
1 1/2"	3/8	1 1/2"	3/8
1 3/4"	1/2	1 3/4"	3/8
2"	5/8	2"	3/8
2 1/2"	1 1/8	2 1/2"	7/8
3"	1 1/4	3"	7/8
3 1/2"	1 1/4	3 1/2"	7/8
4"	1 1/4	4"	7/8
1"	3/8		1 1/4
1 1/4"	5/8		

Thicknesses
1 1/2", 3/8", 1 1/2", 5/8", 3/4", 7/8", 1", 1 1/4", 1 1/2", 1 3/4", 2"

Type	D	T				H*	Recess	
		3/8	1/2	5/8	3/4		P	F
1	1 1/4					1 1/4	1 1/4	5/8
1	1 1/4					1 1/4	1 1/4	5/8
5	7/8					1 1/4	1 1/4	5/8
5	7/8					1 1/4	1 1/4	5/8
1	7/8					1 1/4	1 1/4	5/8
5	7/8					1 1/4	1 1/4	5/8
5	7/8					1 1/4	1 1/4	5/8
1	1					1 1/4	1 1/4	5/8
1	1					1 1/4	1 1/4	5/8
5	1					1 1/4	1 1/4	5/8
5	1					1 1/4	1 1/4	5/8
1	1 1/4					1 1/4	1 1/4	5/8
5	1 1/4					1 1/4	1 1/4	5/8
5	1 1/4					1 1/4	1 1/4	5/8
5	1 1/4					1 1/4	1 1/4	5/8
5	1 1/2					1 1/4	1 1/4	5/8
5	1 1/2					1 1/4	1 1/4	5/8
5	1 1/2					1 1/4	1 1/4	5/8
1	1 1/4					1 1/4	1 1/4	5/8
1	1 1/4					1 1/4	1 1/4	5/8
5	1 3/4					1 1/4	1 1/4	5/8
5	1 3/4					1 1/4	1 1/4	5/8
1	2					1 1/4	1 1/4	5/8
1	2					1 1/4	1 1/4	5/8
5	2					1 1/4	1 1/4	5/8
1	2					1 1/4	1 1/4	5/8
5	2					1 1/4	1 1/4	5/8
5	2					1 1/4	1 1/4	5/8
1	2 1/2					1 1/4	1 1/4	5/8
5	2 1/2					1 1/4	1 1/4	5/8
5	2 1/2					1 1/4	1 1/4	5/8

*Arbors are sizes now in use.

Standard Wheels for CYLINDER GRINDING



Type No. 1

Straight



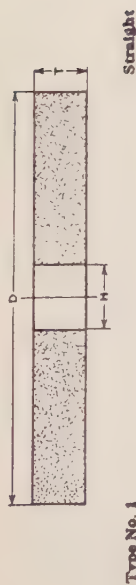
Type No. 5

Recessed One Side

Type	D	T	H	Recess	
				P	F
1	3 1/2	3/4	7/8	1 3/4	3/8
1	3 1/2	3/4	7/8		
5	3 1/2	1	1 1/4	2 3/8	1/4
5	3 1/2	1	1 1/4	2 3/8	1/2
5	4	3/4	1 1/4	1 3/4	3/8
5	4	3/4	1 1/4	2 1/8	1/4
5	4	1	1 1/4	2 1/8	1/2
5	4 1/2	3/4	7/8	1 3/4	3/8
5	4 1/2	3/4			
5	4 1/2	1	1 1/4	2 1/8	1/4
5	4 1/2	1	1 1/4	2 1/8	1/2

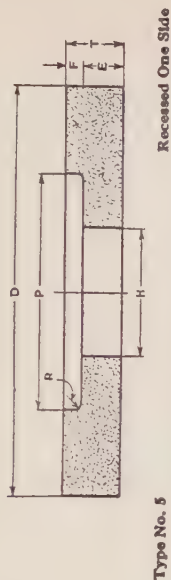
Type	D	T	H	Recess	
				P	F
1	2 1/2	3/4	7/8	1 3/4	3/8
5	2 1/2	3/4	7/8	2 3/8	1/4
5	2 1/2	1	1 1/4	2 3/8	1/2
1	2 3/4	3/4	7/8	1 3/4	3/8
5	2 3/4	3/4	7/8	2 3/8	1/4
5	2 3/4	1	1 1/4	2 3/8	1/2
1	3	3/4	7/8	1 3/4	3/8
5	3	3/4	7/8	2 3/8	1/4
5	3	1	1 1/4	2 3/8	1/2
5	3	3/4	7/8	1 3/4	3/8
5	3	3/4	7/8	2 3/8	1/4
5	3	1	1 1/4	2 3/8	1/2
5	3	1	1 1/4	2 3/8	1/2

**Standard Straight Wheels for
CYLINDRICAL GRINDING**



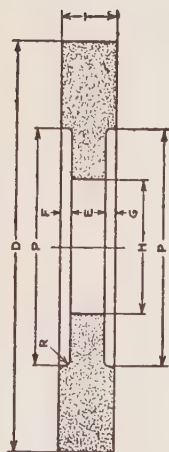
Type No. 1		Straight	
D	T	H	
10	As ordered	5	
12		5	
14		5	
16		5	
18		5	
18		8	
20		5	
20		8	
20		12	
24		5	
24		8	
24		12	
26		12	

**Standard Single Recess Wheels for
CYLINDRICAL GRINDING**



Type No. 5		Recessed One Side	
D	T	H	P
10	As ordered	5	6½
12		5	6½
14		5	8
16		5	8
18		5	8½
18		8	11
20		5	10½
20		8	11
24		5	10½
24		8	11

Standard Double Recess Wheels for
CYLINDRICAL GRINDING



Type No. 7

Recessed Two Sides

D	T	H	P
14	As ordered	5	8
16		5	8
18		8	11
20		8	11
20		12	14 1/4
24		8	11
24		12	14 1/4
26		12	14 1/4

Depth of Recess for 8" and 12" Hole

T	F	G
With "T" less than 2"	0	0
With "T" from 2" up to 2 1/4" inclusive	1/8"	1/8"
With "T" 3" and larger	1/4"	1/4"

Standard
CUTTING-OFF WHEELS

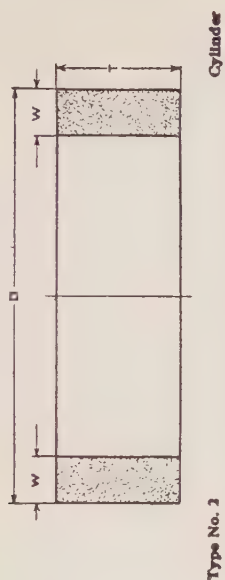


Type No. 1

Straight

D	T		H
6	1/8	1/8	As ordered
6			
7	1/8		
7			
8	1/8	1/8	As ordered
8			
12			
12			

Standard
CYLINDER WHEELS



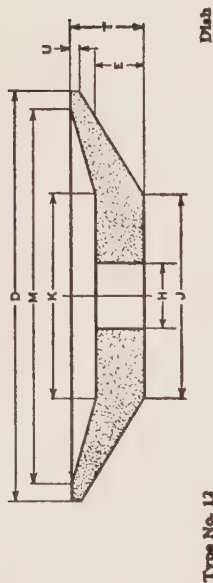
Type No. 2		Cylinder	
D	T	W	
8	4	1	
10	4	1	
12	4	1½	
14	4	1½	
16	4	2	
18	6	2	
20	6	2½	
24	6	2½	
30	6	3	

Standard Straight Wheels with Large Holes for
TOOL GRINDING



Type No. 1		Straight	
D	T	H	
14	As ordered	5	
20		9	
24		10	
26		12	
36		24	

Standard
DISH WHEELS

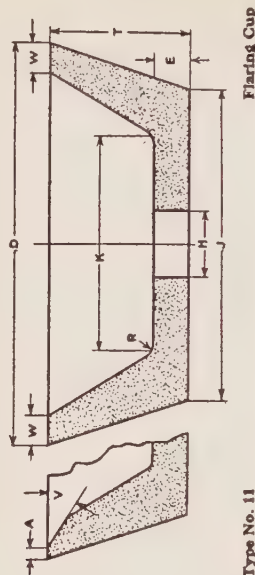


Type No. 12

Dish

D	T	H	E	K and J	U	M
3	1½	As ordered	1½	1½	1½	2¾
3½	1½		1½	1¾	1½	3½
4	1½		1½	2	1½	3¾
4½	1½		1½	2¼	1½	4
5	1½		1½	2½	1½	4½
6	1½		1½	3	1½	5¼
6	2¼		2½	3	1½	5¼
8	2¼		1½	4	1½	7
8	1		1½	4	1½	7

Standard
FLARING CUP WHEELS



Type No. 11

Flaring Cup

Straight Face							Bevel Face		
D	T	H	W	E	J	K	R	A	V
3	1½	As ordered	¾	¾	2¼	1¾	1½	¾	30°
3½	1½		¾	¾	2½	1½	1½	¾	30°
3½	1½		¾	¾	2½	1½	1½	¾	30°
4	1½		¾	¾	3	2½	1½	¾	30°
4½	2		¾	¾	3½	3	1½	¾	30°
5	1¾		¾	¾	3½	3	1½	¾	30°
6	2		¾	¾	4½	3¾	1½	¾	30°
7	2		¾	¾	5	3¾	1½	¾	30°

Standard Straight Cup Wheels for TOOL ROOM GRINDING



Type No. 6

Straight Cup

Straight Face					Bevel Face		
D	T	H	W	E	R	A	V
2½	1½	As ordered	¾	¾	⅙	⅙	30°
3	1½		¾	¾	⅙	⅙	30°
3½	1¾		¾	¾	⅙	⅙	30°
4	1½		¾	¾	⅙	⅙	30°
5	1½		¾	¾	⅙	⅙	30°

Standard Straight Cup Wheels for GENERAL USE

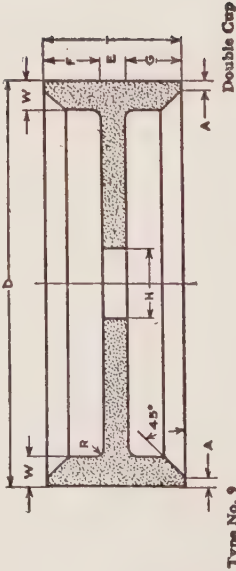


Type No. 6

Straight Cup

D	T	H	W	E
8	4	As ordered	1	1
10	4		1¼	1¼
12	4		1½	1½
14	4		1½	1½
16	5		2	2
20	6		2	2
24	6		2½	2½
30	8		2½	2½

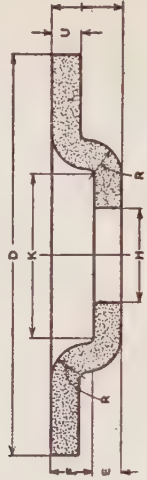
Standard
DOUBLE CUP WHEEL



Type No. 9

D	T	H	W	E	A
4	2	As ordered	$\frac{1}{4}$	$\frac{1}{8}$	$\frac{1}{8}$

Standard
OFFSET WHEELS



Type No. 14

Offset

D	T	H	U	E	K	R
10	1	3	$\frac{3}{8}$	$\frac{3}{8}$	4	$\frac{1}{4}$
12	$1\frac{1}{2}$	3	$\frac{1}{2}$	$\frac{1}{2}$	$4\frac{1}{2}$	$\frac{1}{2}$

GRINDING WHEELS

GRINDING WHEEL MANUFACTURERS' TRADE NAMES

The names by which grinding wheels are designated are practically all coined words derived from carbide of silicon and aluminum oxide. Thus they are difficult to remember in many instances. These trade names must not be confused with abrasive designations which are carbide of silicon and aluminum oxide. The latter often is called manufactured alumina and sometimes, but erroneously, synthetic or artificial corundum. Following are the various grinding wheel trade names arranged in alphabetical order giving the material from which the wheel is made and the maker's name:

- | | |
|--|---|
| A—Abrasive
Aluminum Oxide
Bay State Abrasive Products Co.,
Westboro, Mass. | Borite
Aluminum Oxide
Vitrified Wheel Co.,
Westfield, Mass. |
| Alobrant
Aluminum Oxide
Brantford Grinding Wheel Co.
Inc., Brantford, Ont. | Boro Carbone
Aluminum Oxide
Manhattan Rubber Mfg. Co.
Passaic, N. J. |
| Alowalt
Aluminum Oxide
Waltham Grinding Wheel Co.
Waltham, Mass. | Borolon
Aluminum Oxide
Abrasive Co.
Philadelphia |
| Aloxite
Aluminum Oxide
Carborundum Co.
Niagara Falls, N. Y. | C—Abrasive
Silicon Carbide
Bay State Abrasive Products Co.
Westboro, Mass. |
| Alulion
Aluminum Oxide
Lion Grinding Wheels, Ltd.
Brockville, Ont. | Calcinite
Silicon Carbide
Pittsburgh Grinding Wheel Co.
Rochester, Pa. |
| Aluminite
Aluminum Oxide
Macklin Co.
Jackson, Mich. | Carbo Alumina
Aluminum Oxide
Bridgeport Safety Emery Wheel
Co., Bridgeport, Conn. |
| Aluminoid
Aluminum Oxide
General Grinding Wheel Corp.
Philadelphia | Carbobrant
Silicon Carbide
Brantford Grinding Wheel Co.,
Ltd., Brantford, Ont. |
| Aluminox
Aluminum Oxide
American Emery Wheel Works
Providence, R. I. | Carbo-x
Silicon Carbide
Superior Grinding Wheel Co.
Waltham, Mass. |
| Alundum
Aluminum Oxide
Norton Co.
Worcester, Mass. | Carbolion
Silicon Carbide
Lion Grinding Wheels, Ltd.
Brockville, Ont. |
| Bathite
Aluminum Oxide
White Heat Products Co.
West Chester, Pa. | |

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- Carbolite**
Silicon Carbide
American Emery Wheel Works
Providence, R. I.
- Carbon**
All Wheels
Springfield Mfg. Co.
Bridgeport, Conn.
- Carbolox**
Silicon Carbide
Dominion Abrasive Wheel Co.
Mimico, Ont.
- Carbonoid**
Silicon Carbide
General Grinding Wheel Corp.
Philadelphia
- Carbora**
Silicon Carbide
Cortland Grinding Wheel Corp.
Chester, Mass.
- Carborite**
Silicon Carbide
Vitrified Wheel Co.
Westfield, Mass.
- Carborundum**
Silicon Carbide
Carborundum Co.
Niagara Falls, N. Y.
- Carbowalt**
Silicon Carbide
Waltham Grinding Wheel Co.
Waltham, Mass.
- Clevite**
Aluminum Oxide
Cleveland Abrasive Wheel Co.
Cleveland
- Clevorundum**
Silicon Carbide
Cleveland Abrasive Wheel Co.
Cleveland
- Corex**
Silicon Carbide
Safety Grinding Wheel & Machine Co.
Springfield, O.
- Cresolite**
Silicon Carbide
Canadian-Hart Products, Ltd.
Hamilton, Ont.
- Crystolite**
Silicon Carbide
Macklin Co.
Jackson, Mich.
- Crystolon**
Silicon Carbide
Norton Co.
Worcester, Mass.
- Dayton Alumina Oxide**
Aluminum Oxide
A. A. Simonds Dayton Co.
Dayton, O.
- Dayton Silicon Carbide**
Silicon Carbide
A. A. Simonds Dayton Co.
Dayton, O.
- Electrolon**
Silicon Carbide
Abrasive Co.
Philadelphia
- Excelite**
Aluminum Oxide
Dominion Abrasive Wheel Co.
Mimico, Ont.
- Hytens**
Aluminum Oxide
Precision Grinding Wheel Co. Inc.
Philadelphia
- Lotens**
Silicon Carbide
Precision Grinding Wheel Co. Inc.
Philadelphia
- Natalite**
Aluminum Oxide
National Grinding Wheel Co. Inc.
Buffalo
- Natalon**
Silicon Carbide
National Grinding Wheel Co. Inc.
Buffalo
- Natrundum**
Silicon Carbide
National Grinding Wheel Co. Inc.
Buffalo
- Natumite**
Aluminum Oxide
National Grinding Wheel Co. Inc.
Buffalo
- Orelite**
Aluminum Oxide
Pittsburgh Grinding Wheel Co.
Rochester, Pa.
- Oxaluma**
Aluminum Oxide
Cortland Grinding Wheel Corp.
Chester, Mass.

GRINDING WHEELS

Oxylum	Staralon
Aluminum Oxide	Silicon Carbide
Hampden Corundum Wheel Co.	Detroit Star Grinding Wheel Co.
Springfield, Mass.	Detroit
Radiac	Staralox
All Wheels	Aluminum Oxide
A. P. de Sanno & Son,	Detroit Star Grinding Wheel Co.
Philadelphia	Detroit
Rex	Sterbon
Aluminum Oxide	Silicon Carbide
Safety Grinding Wheel & Ma-	Sterling Grinding Wheel Co.
chine Co.	Tiffin, O.
Springfield, O.	Sterlith
Rexite	Aluminum Oxide
Aluminum Oxide	Sterling Grinding Wheel Co.
Canadian Hart Products Co.	Tiffin, O.
Hamilton, Ont.	Vulcanite
Silexon	All Wheels
Aluminum Oxide	New York Belting & Packing Co.
Bridgeport Safety Emery Wheel	New York
Co., Bridgeport, Conn.	X-l-ite
	Aluminum Oxide
	Superior Grinding Wheel Co.
	Waltham, Mass.

GRITS, GRADES AND BONDS

The grit, or grain as it is sometimes termed, of a grinding wheel refers to the sizes of the abrasive grains of which the wheel is composed. A straight grit is one wherein all the grit particles are of the same size. Thus a 36-grit wheel is made exclusively of No. 36 grain. A combination grit is one composed of several numbers, the numbers and proportions of the various grits having been determined by practical experimentation. The number refers to the size of the coarsest grain. Thus a 24 combination grit has No. 24 grain as its base with the addition of several other numbers. Grinding wheel manufacturers prefer to keep their grit combinations secret. A mixed grit is one composed of two or more kinds of abrasives. A wheel might be made of aluminum oxide backed up with emery. Such a wheel is a mixed grit. As a matter of fact, such wheels are especially valuable for hard, rough usage such as grinding steel castings.

Grade refers to the relative hardness of a grinding wheel. A wheel is in M grade for example, when it is as hard, or offers the same resistance to a grading tool as an M-grade master block. Wheel grades generally are designated by letters of the alphabet. The majority of wheel manufacturers today use

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the universal grade scale but a few prominent makers employ arbitrary lists. These various grades accurately compared are given below.

Universal.....	E	F	G	H	I	J		K	L	M	M	O
Carborundum.....	U	S	R	P	O	N		M	L	K	J	I
Dayton.....	C	D	E	F	G	H		I	J	K	L	M
Dominion.....	2	2½	3	3¼	3½	4		4½	5	5¼	5¾	6¼
National.....			H	I	J	K		L	L½	L¾	M	N
Safety.....	A	A¼	A½	A¾	M	M¼		M½	M¾	P	P¼	P½
Springfield.....	14	13	12	11	10	9½	8½	7½	6	5	4	3

Universal.....	P		Q		R	S	T	U	V	W	X	Y	Z
Carborundum..	H	H+		G+	F	E	E+	D					
Dayton.....	N		O		P	Q	R	S	T	U	V	W	Z
Dominion.....	6½		7		7¼	7½	7¾	8	8¼				
National.....	O		P		Q	R	S						
Safety.....	P¾		I		1¼	L½	1¾	O	O¼	O½	O¾	N	N½
Springfield.....	2		1½		1								

As the foregoing comparison shows, the majority of grinding wheel manufacturers use the letters of the alphabet arranged in sequence, E being a hard and Z a soft. Hard wheels in general, however, seldom go beyond the G grade. Other makers including Dayton, National, and Safety use the letters of the alphabet in arbitrary arrangements. The National and Safety scales employ both letters and figures, while the Dominion and Springfield scales employ figures exclusively. The Carborundum grade scale, while utilizing the letters of the alphabet, is arranged the reverse of other gradings, as U represents a soft and D a hard wheel. This is an individual system devised by the Carborundum Co.

Grinding wheel manufacturers who use the letters of the alphabet in regular order as a grade scale designate the letter M as indicating the medium grade. This has led to some confusion, for in some technical books where a comparison is made between the Carborundum and Norton gradings, the M grades are coincided. This is incorrect as the Carborundum Co.'s M grade is equal in hardness to the Norton Co.'s K grade, which brings the L grades of both scales together. While both the Carborundum and Norton Co. designate M as a medium grade, their M grades are not alike.

In actual grinding wheel manufacturing practice, gradings can be made with a high degree of accuracy. For example, let it be assumed that several grinding wheel manufacturers each agreed to make a 3 x 24-inch wheel for grinding drop forgings,

GRINDING WHEELS

using 20 grit, Q grade and let it be assumed further that they all employed the same abrasive, that is aluminum oxide from the same source or corundum of one lot from a given mine. In this case it is probable that the several wheels would be so nearly alike in grade that it would require the services of an expert to determine any actual difference.

Bond refers to the nature of the binder that holds the wheel together. The various bonds in common use are the vitrified, silicate shellac, bakelite and rubber. Probably 90 per cent of all grinding wheels are made in the vitrified bond. Such wheels are used for both rough and precision grinding operations. The basis of the vitrified bond is clay, vitrification taking place in a kiln. The silicate bond is used for making wheels for cutlery grinding, knife grinding, tool grinding and for bonding ring wheels as used on vertical-spindle surface grinding machines. This is a compact bond and well suited to the foregoing operations. Silicate wheels can be furnished in a much shorter time than can vitrified ones and for this reason silicate wheels were used extensively during the World war. The basis of this bond is silicate of soda.

Shellac and bakelite wheels impart a very high finish. The basis of the shellac bond is ordinary shellac and that of bakelite is a condensation product of phenol and formaldehyde. Such wheels are used for roll grinding, certain cutter sharpening operations and also for making thin, delicate wheels for various operations.

Rubber wheels are very durable. The bond is rubber which in the crude state is mixed with the abrasive material. Vulcanization completes the process. This is the oldest wheel bond known. Rubber wheels are used extensively for rough work such as grinding heavy steel and malleable iron castings and also for making thin wheels for various purposes.

GLAZED AND LOADED WHEELS

The terms *glazed* and *loaded*, as applied to grinding wheels, are often used indiscriminately, but in reality a difference exists between these conditions. When a wheel is glazed, the cutting edges of its exposed abrasive grains are worn off flat so that such a wheel has but little abrasive action. On the other hand, when a wheel is loaded the spaces between the grades are filled with metal particles. This condition frequently exists when

grinding soft materials such as copper or aluminum. The remedy in both cases is to true or dress the wheel. Glazing is caused by using a wheel in too hard a grade for the work at hand, using it for too long a period without truing, or operating it at too great a speed. Loading can be overcome by using filled wheels which are supplied for grinding materials that have a tendency to load the wheel.

HORSEPOWER REQUIRED TO OPERATE GRINDING WHEELS

While the types of motors used to operate grinding wheels can be overloaded heavily, the following data will be found satisfactory under general conditions:

Ordinary wheels as used for snagging castings and forgings, tool grinding, general grinding, precision grinding, etc.

Wheel diameter, inches	Horsepower
6	$\frac{1}{4}$ to $\frac{1}{2}$
8	$\frac{3}{4}$
12	$3\frac{3}{4}$
14	5
16	$6\frac{1}{2}$
18	$7\frac{1}{2}$
20	$8\frac{1}{2}$
24	10
30	15

The following data pertains to wheels used on various standard type machines:

BLANCHARD SURFACE GRINDERS

Wheel diameter, inches	Horsepower
10	10
18	25
27	60

DIAMOND MACHINE CO. SIDE SURFACER

Wheel diameter, inches	Horsepower
30	30

PRATT & WHITNEY VERTICAL SURFACE GRINDERS

Diameter of wheel, inches	Horsepower
8	$7\frac{1}{2}$
15	15 to 25
22	30

The power required to operate grinding wheels under the foregoing conditions will be at least 30 per cent less than the rating when individual drives are considered for provision is

GRINDING WHEELS

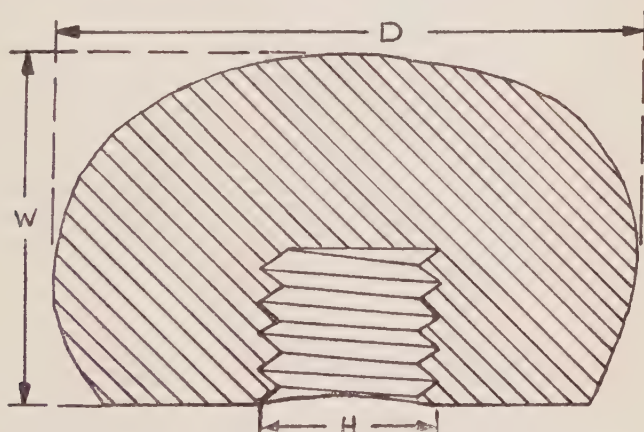
made for a heavy overload. When several machines are to be driven by one motor through a line shaft, it is safe to deduct from 30 to 50 per cent from the foregoing figures.

MASTER BLOCKS

Master blocks are standards used by grinding wheel manufacturers to fix wheel grades within arbitrary limits. These blocks are made carefully from predetermined mixtures of bond and abrasive. They are not used in every day practice in checking wheel grades; rather they are employed as a court of last appeal in determining doubtful grades. The master blocks of one grinding wheel manufacturer may not compare with those of another, grade for grade. This is because each manufacturer has his own idea of what degree of hardness constitutes a certain grade. In making up master blocks, a large number are put through the process and those selected as final which come as close as possible to a given standard, say a wheel made by another grinding wheel manufacturer.

POT BALLS

Pot balls are special wheels used for finishing hollow ware, a favorite shape being shown in the accompanying illustration.



POT BALL FOR GRINDING HOLLOW WARE

This is called a round-shape pot ball to distinguish it from another type with a flat bottom.

Dimension D generally is 5 inches. W is anywhere from 3

to 6 inches. *H* always is $1\frac{3}{4}$ inches with a $\frac{3}{8}$ -inch pitch right-hand thread. Pot balls generally are carbide of silicon, as hollow ware to be finished by grinding is cast iron. Aluminum hollow ware is not ground, being finished generally by buffing on set-up wheels.

PYROMETRIC CONES

These are devices used for controlling kiln heats in the vitrifying of grinding wheels and other ceramic objects. They are composed of clays of various melting points which are known definitely. Three are mounted on one base. The first cone will become plastic and topple over when the kiln is at its so-called red heat. The next one succumbs as the low melting point of the wheel bond, while the third cone droops when the kiln has reached a full heat of approximately 2500 degrees Fahr.

REBUSHING GRINDING WHEELS

Equipment in any manufacturing plant represents additions that have been made from time to time so that in the case of grinding stands it often is found that it is necessary to carry in stock wheels of like diameters, widths, grits and grades, but with varying size holes to fit different spindles.

In instances of this kind it is a good plan to purchase the wheels with holes to fit the largest spindle. Then to fit the other spindles the holes can be fitted with wood bushings which can be obtained from any grinding wheel manufacturer.

The lead bushings can be sawed in two, knocked out and others fitted. However, this process involves the use of a special chuck for centering the wheel and a supply of arbors of different sizes. While these chucks are used frequently in grinding wheel agencies, it is doubtful if it would pay to install one in the wheel consumer's plant.

SAGERS

Sagers are fire clay receptacles in which grinding wheels are placed for vitrifying in kilns. They usually are made up of $\frac{3}{4}$ new material and $\frac{1}{4}$ old sagers which are crushed and ground. The sagers are not long lived although they will stand several kiln heats. It is customary to employ a number of potters in the grinding wheel factory whose duty it is to keep up the supply of sagers. Small sagers are made solid. They are

GRINDING WHEELS

circular with the wall at an angle of 90 degrees with the bottom. They average from 18 inches in diameter and down and about 6 inches deep. Large sagers are made in sections four quarters forming the bottom and a number of pieces the sides.

SECTIONAL WHEELS

Sectional wheels, sometimes called segmental wheels, are abrasive cylinders composed of sections that fit a special holder. The object is to provide a wheel with slight clearances between the sections to provide a path for the loose abrasive and metal as it is ground away. Another factor in favor of sectional wheels



IMPROVED CYLINDER WHEEL

is that they eliminate the danger of breaking which always is a detrimental factor in handling these large cylinders. Further, by the use of sectional wheels, losses in the manufacturing process are avoided.

The accompanying illustration is a wheel designed by the American Emery Wheel Works to incorporate the chief advantages of sectional and solid wheels. The depressions on the inside of the rim are for chip clearance.

SELECTING STEELS BY THE SPARK METHOD

Various kinds of steels can be designated readily by testing them on a grinding wheel. John F. Keller furnished the following data pertaining to this subject:

Fig. 1.—A piece of wrought iron free from carbon. If held

against the grinding wheel the end of the bar will be heated by friction; as the small particles are thrown from the wheel they will follow a straight line which becomes broader and more luminous some distance from the source of heat, and then disappear as they started. This is probably due to the action of oxygen of the air on the heated particles requiring some time to act. Note—Touch material lightly on wheel; observe individual spark.

Fig. 2—Mild steel which contains a small percentage of carbon. The effect is at once noticeable by a division or forking



SPARKS THROWN BY VARIOUS KINDS OF STEEL

of the luminous streak; this is owing to the presence of carbon which is acted upon by the maximum heat of the iron spark, which then burns explosively, causing a break in the original heavy lines.

Fig. 3—The lower grades of tool steel which contain from 0.50 to 1.00 per cent carbon. The iron lines becomes less and less conspicuous; the forking of the luminous streak occurring very

much more frequent, often subdividing; the lower the carbon the less sparks and further from the source of heat.

Fig. 4—In the higher grades of carbon steels, the iron lines are practically eliminated, with an increase of the star-like explosions which often divide and subdivide, causing a beautiful display of figures. This is probably due to the iron and carbon becoming so united that they are most easily attacked by the oxygen. Hence the great danger of burning steel in the fire. It would be well to state that the higher the percentage of carbon the more profuse the explosion and the shorter the distance from their source of heat.

Fig. 5.—Chromium and tungsten high speed steels are very easily determined by the spark test. The particles seem to follow a broken line with a very slight explosion; just before they disappear the color is of chrome yellow, and show no trace of a carbon spark.

Fig. 6—Manganese in tool steel above a certain per cent is an injurious element. The characteristic of the manganese spark is that it widely differs from the carbon spark in that it seems to shoot or explode at right angles from its line of force. Each dart is subdivided into a number of white globules. With a little practice, the trained eye will soon detect the slightest trace of manganese in the iron or steels.

Fig. 7—Mushett steel, the grade of air hardening or high speed steel. It is very easy to distinguish from other steels as the particles follow a broken line and are very, very dark red, with an occasional manganese spark.

Fig. 8—Represents the spark as thrown from a special steel manufactured and to be used especially for magnets. It clearly demonstrates the advantage of this method of selecting steels by comparison; in other words, mark your favorite brands or grades and compare them with others. By practicing this method, there will be fewer taps and reamers made out of machinery steel, with a corresponding decrease in the number of forgings made out of metals that are too high in carbon.

SELECTION OF WHEELS

The selection of grinding wheels is governed by a number of factors so that only general instructions can be given. Alumina abrasives, such as manufactured, or natural corundum

and emery are used for grinding steel and other high tensile strength materials, while carbide of silicon gives better results on cast iron and other low tensile strength materials. Non-metallic substances such as wood, bone, pearl, fiber, leather, etc., are best ground with carbide of silicon. To some extent the finish desired determines the abrasive to employ, but to a slight extent only. Thus, while emery gives a finer finish than any other abrasive, it is not used for grinding wheel manufacture to any great extent as it is slow cutting. Carbide of silicon imparts an excellent finish on steel, but alumina abrasives have taken its place on this work. Some years ago, however, before the perfection of manufactured alumina, carbide of silicon was employed largely for such steel grinding operations as saw gumming, grinding automobile engine crankshafts, etc.

The following list gives wheel grading compiled by the Carborundum Co. The gradings are general in scope and are not final in every instance. Three gradings are given, coarse, medium and fine.

Grits range from size 10, the coarsest generally used in the manufacture of grinding wheels, to size 220, the finest, as follows: 10, 12, 14, 16, 20, 24, 30, 36, 40, 50, 60, 70, 80, 90, 100, 120, 150, 180, 220.

The size of the grit is determined by the number of meshes to the inch of the screen through which the grains pass in sieving, or grading.

In powders carborundum and aloxite are graded in the following F, FF, FFF, 280, 320, 400, 500, 600. The F, FF, FFF powders are graded commercially, the other powders under microscopic control.

Combination grits are indicated by three numerals, the first two designating the grit size and third the combination number. For example, 246 grit means 24 grit with the number 6 combination.

E is the hardest, and W, the softest grade. Hardness is controlled by the character and proportions of the bonding material used. Carbo. is carborundum; alox., aloxite; vit., vitrified; sil., silicate, shel., shellac. Redmanol is an elastic or bakelite bond. AA and LL refer to special abrasives.

GRINDING WHEELS

Class of Work	Abrasive Material	GRADINGS		
		Coarse Hard	Medium Medium	Fine Soft
Agate				
Roughing	Carbo. Vit.	60 -K-G4	120-K-G4	
Finishing	Carbo. Vit.			2F-K-G4
Aluminum				
Cylindrical	Carbo. Vit.	24 -M-G3	36 -M-G3	403-P-CF
Snagging (alloys)	Carbo. Vit.	16 -H + HD 16 -I-G6	36 -J-G5	60 -K-G4
Snagging (pure)	Semite Shel.	20 -2-S8D		
Surfacing-vertical	Carbo. Shel. Carbo. Vit. Carbo. Redmanol	16 -4-C4B 24 -R-D4L	30 -5-C5B 36 -T-D2L 30 -13-C13R	
Anvils (Surfacing)				
Chilled iron	Carbo. Vit	20 -H-B8		
Steel	Alox. Vit.	16 -G-34	20 -H-33	
(Segment Wheels)	Alox. Vit.	16S-N-27		
Armatures (Cylindrical)	Alox. Vit.	301-K-30	401-M-28	
Axes				
Edging	Alox. Vit.	16 -F-35	20 -G-34	
Surfacing	Alox. Vit.	24 -H-33	40H-H-33	60 -H-D846
Axles				
Automobile (cylindrical)	Alox. Vit.	301-J-31	246-J-31	401-K-30
Car (railway)	Alox. Vit.	301-K-30	246-K-30	246-M-28
Housings (auto)		301-J-31	246-K-30	401-M-28
Balls				
Soft—first roughing ...	Alox. Vit.	40 -D-AD849	60 -D-AD849	
Soft—second roughing..	Alox. Vit.	60 -D-AD849	80 -D-AD849	
Soft—finishing	Alox. Vit.		90 -D-AD849	120-D-AD849
Hard—roughing	Alox. Vit.	60 -D-AD849		
Hard—finishing	Alox. Vit.		90 -D-AD849	120-D-AD849
Hard—polishing	Carbo. Vit.			F-D-108
Hard—polishing (small balls)	Alox. Vit. Carbo. Vit.			180-D- AD1016C F-D-400A
Ball Races (Soft Steel)				
Surfacing (vertical)	Alox. LL	16 -R-L5	24 -S-L4	30 -S-L4
Hard Steel & Alloys:				
Cylindrical—Traverse	Alox. Vit.	301-K-30	301-M-28	401-M-28
O.D. of cups—Straight	Alox. Vit.	401-M-28	401-O-26	60 -O-26
in				
Cylindrical (Center- less)				
O. D. of cups	Alox. Vit.	60 -N-27	60 -P-25	80 -S-23
Surfacing (Vertical)	Alox. LL Alox. Redmanol	24 -R-L5 30 -13-K13R	30 -S-L4 36 -13-K13R	36 -T-L3 50-12-K12R
Rough grooving in- ner race	Alox. LL Alox. Rubber	50 -N-L8 36 -KBN	60 -N-L8 60 -KBN	80-KBN
Finish grooving inner face	Alox. Shellac Alox. Rubber	60 -5-K5A 60 -KBN	80 -5-K5A 80 -KBN	

THE ABRASIVE HANDBOOK

Class of Work	Abrasive Material	GRADINGS		
		Coarse Hard	Medium Medium	Fine Soft
Rough grooving outer race	Alox. Rubber	36 -KBN	60 -KBN	
	Alox. Shellac	60 -5-K5A	80 -5-K5A	
	Alox LL	50 -N-L3	60 -N-L3	
Finish grooving outer race	Alox Rubber	70 -KBN	100-KBN	
	Alox. Shellac			100-5-K5A 120-6-K6A
Bore grinding	Alox. Vit.	60 -K-30	60 -M-23	80 -P-25
Bath Tubs (Surfacing)	Carbo. Vit.	20 -G+VA	24 -G+VA	
		16S-H+HD	24 -H+HD	24 -H-G7
		16S-H-G7		
Billets				
High Carbon Steel & High Speed Steel Swing Frame	Alox. Vit.	14 -G-1190	16 G-1190	16 -H-1191
	Alox. Vit.	16 -G-64	16 -H-33	20 -H-33
Flexible Shaft	Alox. Vit.	20 -G-064	24 -G-064	24 -H-063
Centerless (Drill Rod & Rounds) ..	Carbo. Vit.	36 -G-G8	60 -G-G8	
	Alox. Vit.	40 -H-33	60 -H-33	80 -K-30
Alloy Steel:				
Swing frame	Alox. Vit.	12 -G-1190	14 -H-1191	16 -H-1191
	Alox. Vit.	12 -G-64	14 -G-64	16 -G-64
Flexible Shaft	Alox. Vit.	20 -G-064	24 -G-064	24 -H-063
Centerless (Drill Rod & Rounds) ..	Carbo. Vit.	36 -G-G8	60 -G-G8	
	Alox. Vit.	40 -H-33	60 -H-33	80 -K-20
Bits				
Auger	Alox.			
	Redmanol	36 -7-K7RB	50 -7-K7RB	70 -8-K8S
	Alox. Rubber	36 -KBP	50 -KBP	70 -KBP
Carving	Alox. Vit.		100-J-31	120-J-31
	Alox. Vit.	365-M-D498	60 -M-D498	80 -M-D498
Bolts (Automobile)				
Cylindrical	Alox. Vit.	301-K-30	401-K-30	401-M-23
Cylindrical (centerless) ..	Alox. Vit.	60 -J-31	60 -L-29	80 -K-30
Brake Shoes				
(Chilled iron) Snagging	Carbo. Vit.	166-G+VA	20 -G+VA	24 -H+HD
	Carbo Vit.	166-G+MC-10	16 -G+MC-10	
Brass				
Cylindrical	Carbo Vit.	24--M-G3	36 -M-G3	403-P-CF
Cut off	Carbo Rubber	16 -CBR	30 -CB	60 -CB
	Carbo. Redmanol	50C-4	50C-6	70C-4

GRINDING WHEELS

Class of Work	Abrasive Material	GRADINGS		
		Coarse Hard	Medium Medium	Fine Soft
Internal	Carbo. Vit.	36 -M-G3	60 -M-G3	
Snagging:				
Under 12" diameter...	Carbo. Vit.	30 -I-G6	36 -I-G6	50-J-G5
Over 12" diameter...	Carbo. Vit.	16 -H+HD	24 -I-G6	36 -I-G6
Surfacing (vertical).	Carbo. Vit.	24 -P-D5L	30 -R-D4L	36 -T-D2L
Brick				
Hard	Carbo. Vit.	14 -K-G4	16 -M-G3	
Soft	Carbo. Vit.	14 -I-G6	16 -J-G5	
Broaches (Sharpening)	Alox. AA	36A-M-681	46A-N-680	54A-P-678
Bronze				
Soft:				
Cylindrical	Carbo. Vit.	24 -M-G3	36 -M-G3	403-P-CF
Cut off	Carbo Rubber	16 -CBR	30 -CBR	60-CBR
	Carbo.			
	Redmanol	50C-4	50C-6	70C-4
Internal	Carbo. Vit.	36 -M-G3	60 -M-G3	
Snagging:				
Under 12" diameter...	Carbo. Vit.	30 -I-G6	36 -I-G6	50 -J-G5
Over 12" diameter...	Carbo. Vit.	16 -H+HD	24 -I-G6	36 -I-G6
Surfacing:				
Horizontal	Carbo. Vit.	24 -N-E2-½	30 -P-E1-½	36 -P-E1-½
Vertical	Carbo. Vit.	20 -P-D5L	30 -R-D4L	36 -T-D2L
Hard:				
Cylindrical	Alox. Vit.	301-K-30	401-K-30	401-M-28
Cut off	Alox. Rubber	16-KBR	24 -KCR	
	Alox.			
	Redmanol	50K-4	50K-6	70K-4
Internal	Alox. Vit.	40 -L-29	60 -N-27	60 -P-25
Snagging	Alox. Vit.	16 -H-33	20 -H-33	24 -H-33
Surfacing				
Horizontal	Alox. LL	36 -P-L6	40 -R-L5	50 -T-L3
Vertical	Alox. LL	20 -R-L5	24 -S-L4	30 -T-L3
Buhrstones (Grooving)				
1/32" thick and under.	Carbo Rubber	50 -CAR		
Under ¼" to 1/16"....	Carbo Rubber	24 -CAR	30 -CAR	50 -CBR
	Carbo.			
	Redmanol	50C-4S	70C-4S	
¼" thick and over....	Carbo. Vit.	24 -J-G5	30 -K-G4	
Bushings				
Cast iron:				
Cylindrical	Carbo. Vit.	36 -K-G4	36 -M-G3	403-P-CF
Internal	Carbo. Vit.	36-N-E2-½	36S-S-OH	36S-T-OI
		303-S-OH		
Hardened steel:				
Cylindrical	Alox. Vit.	401-M-28	401-O-26	60 -P-25
Internal	Alox. Vit.	40 -M-D498	50 -N-D497	60 -O-D496
		50-K-30	60 -M-28	60 -O-26
Cams				
Roughing	Alox. Vit.	24 -F-65	30 -G-64	
		24 -G-64		
Semi Finish	Alox. Vit.	246-P-25	401-P-25	
Finishing	Alox.			
	Redmanol	70 -6-K6R	70 -8-K8R	

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Class of Work	Abrasive Material	GRADINGS		
		Coarse Hard	Medium Medium	Fine Soft
Cam Shaft Bearings	Alox. Vit.	301-K-30	401-M-28	401-Q-26
Car Wheels				
Chilled Iron:				
Flange	Alox. Vit.	20-E-AD1189	20 -E-66	30 -E-66
Tread	Carbo. Vit.	14 -I-G6	16 -I-G6	24 -I-G6
Regrinding	Alox. Vit.	16 -H-63	16 -K-30	
	Carbo Vit.	16 -H+HD	16 -I-G6	
Steel (Manganese)				
Flange	Alox. Vit.	16 -F-65		
Tread	Alox. Vit.	16 -F-65		
Carbon				
Hard:				
Cut off	Carbo Rubber	16 -CBR	24 -CBR	36 -CBR
	Carbo.			
	Redmanol	40C-4	50C-4	60C-4
Surfacing	Carbo. Vit.	12 -M-G3	36 -P-E1½	60 -R-E1
Soft:				
Cut off	Carbo Rubber	16 -CBR	24 -CBR	36 -CBR
	Carbo.			
	Redmanol	40C-4	50C-4	60C-4
Surfacing	Carbo. Vit.	12-M-G3	36 -P-E1½	60 -R-E1
Centerless				
Hard & soft	Carbo. Vit.	365-J-G5	60 -K-G4	
Carbon copper brushes				
Cut off	Carbo.			
	Redmanol	40C-6	50C-6	70C-6
Card, Clothing	Alox. Rubber	80-KBR		180-KCL
Cast Iron				
Cylindrical	Carbo. Vit.	24 -K-G4	36 -K-G4	36 -M-G3
	Carbo.			365-M-B3
	Redmanol	36 -12-C12R	60 -10-C10R	
Cylindrical (centerless)	Carbo. Vit.	24 -K-G4	36 -K-G4	36 -P-E1½
		365-J-G4	36 -M-G3	60 -M-G3
Internal	Carbo. Vit.	24 -M-G3	36 -M-G3	60 -M-G3
Snagging	Carbo. Vit.	16 -G+VA	20 -G+VA	24 -G+VA
Surfacing				
(Segment wheels) ...	Carbo. Vit.	16 -J-G5	141-N-JD	14 -P-JF
Vertical	Carbo. Vit.	16 R-D4L	20 -S-D3L	30 -T-D2L
	Alox. LL	20 -P-L6	20 -S-L4	30 -T-L3
Horizontal	Carbo. Vit.	24 -N-E2½	30 -P-E1½	36 -P-E1½
Centerless Grinders				
All Standard Makes:				
Soft Steel:				
Roughing	Alox. Vit.	40 -I-32	40 -K-30	40 -N-27
		60 -H-33	60 -J-31	60 -L-29
Finishing	Alox. Vit.	80 -K-30	80 -M-28	80 -P-25
	Alox. Rubber		80 -KC	100-KDX
	Alox.			
	Redmanol			150-6-K6R
Hardened steel;				
Roughing	Alox. Vit.	60 -L-29	60 -N-27	60 -P-25

GRINDING WHEELS

Class of Work	Abrasive Material	GRADINGS		
		Coarse Hard	Medium Medium	Fine Soft
Finishing	Alox. Vit. Alox. Rubber Alox. Redmanol Alox. Silicate	80 -M-28	80 -O-26 80 -KC	80 -P-25 100-KDX 150-6-K6R 100-I-SI
Cast Iron:	Carbo. Vit.	365-J-G5	36 -M-G3	36 -P-E1-½ 60 -M-G3
Feed Wheels all for Centerless Machines..	Alox. Rubber	80 -KC		
Chain Links				
Hard Iron	Carbo. Vit. Alox. Vit.	16 -F-MC11	20-F-MC11 30 -E-66	
Manganese	Alox. Vit.	24 -F-65		
Chasers				
Grinding Throats.....	Alox. Redmanol	60 -9-K9T	80 -9-K9T	
Surfacing	Alox. AA	36A-M-681	46A-N-680	46A-P-678
Clay Products				
Surfacing (Cups & Cylinders).. (or Segments)	Carbo. Vit.	12 -M-E3	12 -P-E1½	16-P-E1½
Chilled Iron				
Snagging	Carbo. Vit.	16 -G+VA 16 -H+HD	20 -G+VA 20 -G+HD	24 -G+VA 24 -H+HD
Surfacing:				
Vertical	Carbo. Vit.	20 -P-D5L	30 -R-D4L	36 -T-D2L
Horizontal	Carbo. Vit. Carbo. Redmanol	24-N-E2½ 40 -13-C13R	30 -P-E1½ 60 -13-C13R	36 -P-E1½
Rolls—See Rolls				
Commutators				
Roughing (wheels) ...	Carbo. Shel.	24 -9-C9C	50 -9-C9C	
Finishing (wheels) ...	Carbo. Shel.			100-9-C9C
Roughing (blocks & rubs)	Alox. Shellac	50 -9-K9C		
Finishing (blocks & rubs)	Carbo. Shel.			70 -9-C9C
Concrete				
Surfacing	Carbo. Vit.		24 -K-G4	
Surfacing—Hand rub fluted	Carbo. Vit.		20 -G6	
Connecting Rods				
Internal	Alox. Vit.	36 -L-D840	36 -M-D498	
Surfacing (vertical) ..	Alox. LL	20 -P-L6	24 -R-L5	30 -R-L5
Copper				
Cut off	Carbo Rubber Carbo. Redmanol	16 -CBR	24 -CBR 50C-6	36 -CBR 70C-4

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Class of Work	Abrasive Material	GRADINGS		
		Coarse Hard	Medium Medium	Fine Soft
Cylindrical	Carbo. Shel.	36 -3-C3A	60 -3-C3A	80 -4-C4A
	Carbo.			
	Redmanol			150-4-C4R
Snagging	Carbo. Vit.	36 -I-G6		60 -J-G5
Surfacing	Carbo. Shel.	40 -5-C5A	60 -5-C5A	80 -5-C5A
Rolls—See Rolls				
Couplers and Drawbars				
Snagging	Alox. Vit.	10D-G-64		14 -H-63
Crankshafts				
Turned:				
Roughing	Alox. Vit.	301-H-33	301-I-32	
		301-H-63		
Finishing ...	Alox. Vit.		366-J-31	
			366-K-30	401-L-29
Unturned:				
Roughing	Alox. Vit.	301-G-64	366-J-31	
Finishing	Alox. Vit.		366-K-30	401-L-29
			401-L-29	
Regrinding	Alox. Vit.	401-K-30	401-L-29	
Snagging (balancing)	Alox. Vit.	16 -G-64	16 -H-63	20-G-34
Cutlery (Table & Pocket)				
Bolster grinding	Alox. Rubber	50 -KCR	60 -KCR	80-KCR
Knives (Hemming wheels)	Alox.			
Carbon steel	Redmanol	50- 9-K9R	70 -9-K9R	120-9-K9R
	Alox.			
Stainless steel	Redmanol	50-11-K11R	70 -11-K11R	120-11-K11R
Knives:				
Surfacing off hand	Alox. Silicate	90 -I-S1	100-I-SI	120-J-SJ
Knives—See Knives				
Cutters (Sharpening)				
(Formed				
Gear	Alox. Vit.	401-P-25	401-R-24	60 -T-22
		50-N-D497		
Hob	Alox. AA	46A-N-680	54A-P-678	60A-P-678
Insert Tooth Mill- ing)	Alox.			
	Redmanol	50-12-K12T	60 -12-K12T	
Cylinders (Gas Engine & Auto)				
Internal				
New Cylinders	Carbo. Vit.	36 -N-E2½	36 -P-E1½	303-S-OH
Regrind	Carbo. Vit.	303-S-OH	303-T-OI	
Honing (Sticks)			365-S-OH	365-T-OI
Roughing	Carbo. Vit.	60 -G8		
Finishing			180-G6	220-G6
Dies (Chilled Iron)				
Surfacing	Carbo. Vit.	24 -H+HD		
		20 -I-G6		
Drawbars & Couplers ...	Alox. Vit.	10D-G-64		14 -H-63

GRINDING WHEELS

Class of Work	Abrasive Material	GRADINGS		
		Coarse Hard	Medium Medium	Fine Soft
Drills (High Speed Steel)				
Sizing (cylindrical)...	Alox. Vit.	301-J-31	401-K-30	401-M-28
Centerless (cylindrical)	Alox. Vit.	60-H-33		
	Alox. Rubber	80-KC		
Fluting	Alox.			
	Redmanol	60 -8-K8S	80 -8-K8S	
	Alox. Rubber	60 -KCW	80 -KCW	
Point Thinning	Alox.			
	Redmanol	50K-6	60K-8	
Sharpening				
(Automatic)	Alox. Vit.	30A-N-Z11	40 -N-27	50 -M-28
Shanks	Alox. Vit.	401-K-30	401-M-28	60 -M-28
Backing off	Alox. Vit.	401-K-30	401-M-28	
Drop Forgings (See Forgings)				
Files				
Surfacing	Alox. Vit.	24 -K-30	241-M-28	
Edging	Alox. Vit.			30-G-64
Fluting				
See Taps, Drills Bits				
Forgings				
Snagging (hand) ...	Alox. Vit.	16 -F-65	20 -F-65	30 -G-64
Surfacing	Alox. Vit.	24 -J-30	30 -K-30	
Fork Tines	Alox. Vit.	208-E + AD702		
Frogs and Switches (Manganese)				
Snagging (swing frame)	Alox. Vit.	12S-F-65	14S-G-64	16S-H-63
Surfacing	Alox. Vit.	14S-H-63	14S-I-32	14S-K-30
Grooving	Alox. Vit.	14S-H-63	16S-J-31	20 -N-27
Hole Grinding	Alox. Vit.	24 -M-28		
Portable Grinding ...	Alox. Vit.	20 -G-64	24 -H-63	
Gauges				
Plug (cylindrical) ...	Carbo. Vit.			3F-P-WF
	Alox. Shellac			3F-5-K5A
Gears				
Cleaning between teeth:				
Cast Iron	Carbo Rubber	24 -CBA	36 -CBA	60 -CBA
Steel (hardened) ..	Alox. Vit.	24 -H-63	36 -H-63	
Internal	Alox. Vit.	40 -L-D840	60 -M-D498	60 -P-D498
	Alox. Vit.	60 -K-30	60 -M-28	60 -P-25
Surfacing—vertical ..	Alox. LL	24 -P-L6	24 -R-L5	36 -T-L2
Stoning Rubs	Carbo. Vit.		2F-G12	
Glass (Cut)				
Checkering and fine cutting	Alox. Vit.	180 to 1F-F to 1		
Floral cuts (multiple or gang mitres)	Alox. Vit.	180 to 1F-F to K		

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Class of Work	Abrasive Material	GRADINGS		
		Coarse Hard	Medium Medium	Fine Soft
Medium depth cuts, pressed ware	Alox. Vit.	120 to 180-H to N		
	Alox. Vit.	80 to 100-K-to P-20	bond	
Spotting and punties. .	Alox. Vit.	80 to 1F-H to L		
Scalloping	Alox. Vit.	220 to 1F-J to L		
Fluting	Alox. Vit.	100 to 1F-J to L		
Flatting	Alox. Vit.	100 to 1F-J to L		
Lighting Ware:				
Mitre cuts—smoothing	Alox. Vit.	120 to 1F-F to K		
Fine cuts—smoothing	Alox. Vit.	180 to 1F-F to K		
Punites—smoothing .	Alox. Vit.	80 to 100 H to K		
Spotting—smoothing .	Alox. Vit.	80 to 120 H to R		
Lamp shades:				
Edge grinding—dry..	Carbo. Vit.	60 to 80-J to M		
Edge grinding—wet.	Carbo. Vit.	80 to 120-I to J		
Electric light globes, air tight, wet	Carbo. Vit.	80 to 120-I to J		
Air vent grinding of gas globes, wet....	Carbo. Vit.	80 to 220-I to N		
Reaming, wet	Carbo. Vit.	60 to 120-G to K		
Overblow, wet or dry.	Carbo. Vit.	60 to 120 L to P		
Tumbler Grinding:				
Edge Grinding	Carbo. Vit.	120 to 180 M to Q		
Edge Grinding	Alox. Vit.	100 to 180 E to H		
Edge beveling	Alox. Vit.	180 to F-I to K		
Fluting	Alox. Vit.	80 to 180-I to K		
Cracking off Wheels & Sticks	Carbo. Vit.	100 to 180 G to K		
Optical Lenses—Edge Grinding				
Roughing rimmed lenses	Carbo. Vit.	220	-L to O	
Smoothing rimmed lenses	Alox. Vit.	80 to 180-J to N		
Smoothing rimless lenses	Alox. Vit.	80 to 180-J to N		
Perfection bi-focals, etc.	Alox. Vit.	80 to 180-K to P		
Glass				
Plate Glass:				
Beveling—Roughing vertically	Carbo. Vit.		60 to 150 L to R	
Beveling—smoothing	Alox. Vit.		120 to 180 F to H	
Edgework—				
Roughing	Carbo. Vit.		60 to 180 K to M	
Edgework—Semi-smoothing	Carbo. Vit.		180 to 3F-H to K	
	Alox. Vit.		150 to J to L	
Edgework—				
Smoothing	Alox. Vit.		120 to 220 F to H	
Edgework (Webber machine)	Alox. Vit.		150-J-31	
Notching—				
Roughing	Carbo. Vit.		100 to 150 L to O	
Notching—Smooth-ing	Alox. Vit.		120 to 180 F to H	

GRINDING WHEELS

Class of Work	Abrasive Material	GRADINGS		
		Coarse Hard	Medium Medium	Fine Soft
Mitre Cutting— Roughing	Carbo. Vit.		70 to 120 L to P	
Mitre Cutting— Smoothing			180 to 1F H to K	
Cash Holes	Carbo. Vit.		100 to 120 K	
Hand pulls—finger slots	Alox. Vit.		120	H
Glass Miscellaneous				
Cutting glass tubing..	Carbo. Vit.	180 to 220-H to I		
Glass tile wheels.....	Carbo. Vit.	60 to 220-I to M		
Opalite, Vitrolite, Car- rara, etc.—roughing..	Carbo. Vit.	60 to 220-I to M		
Potters Wheels (smoothing out burns)	Carbo. Vit.	180 to 220-H to K		
Gem Grinding (roughing)	Carbo. Vit.	60 to 120-H to L		
Gem Grinding (smoothing)	Carbo. Vit.	150 to F-H to L		
Blocking out and shap- ing Mineral Stones..	Carbo. Vit.	60 to 120-H to L		
Granite				
Slotting	Carbo. Redmanol	20 -6-C6T		
	Carbo. Shel.	141-2-A3M		
Polishing	Carbo. Vit.	40 -M-G3		
Guide Bars				
Ring and segment wheels	Alox. Vit. Alox. Silicate	16 -M-28 141-N-SN		
Hammers and Hatchets				
Claws, grinding be- tween	Alox. Rubber	50 -KCR		
Neck grinding	Alox. Rubber	14 -KDH	24 -KDH	
Surfacing	Alox. Vit.	24 -H-33	36 -I-32	
Knives				
Barker and chipper..	Alox. Sil.		303-P-SP	36 -S-SS
Butcher (See Cutlery)				
Hog	Alox. Sil.		303-P-SP	36 -S-SS
Leather Fleshing (block)	Alox. Vit.		24 -D840	
Leather Shaving	Alox. Vit.	502-I+D845	70 -J-D842	
Leather Splitting	Alox. Shellac Alox. Redmanol		30 -8-K8A	
			40 -14-K14T	
Moulding	Alox. Vit.		40 -M-D498	60 -M-D498
Paper	Alox. Sil.		303-P-SP	36 -S-SS
Pocket (See Cutlery),	Alox. Sil.	90 -I-SI	120-J-SJ	
Section Mower	Alox. Sil.	36 -K-SK	36 -L-SL	
Sugar Beet.....	Alox. Shellac	36 -4-K4B		
Sticker	Alox. Vit.	40 -M-D498	60 -M-D498	
Tobacco	Alox. LL Alox. Vit.	40 -O-L7 50 -N-27		

THE ABRASIVE HANDBOOK

Class of Work	Abrasive Material	GRADINGS		
		Coarse Hard	Medium Medium	Fine Soft
Rag	Alox. Silicate	303-P-SP	36 -S-SS	
Table (See Cutlery) ..				
Veneer	Alox. Sil.	303-P-SP	36 -S-SS	
Shear Blades	Alox. Sil.	16 -L-SL	24 -J-SJ	
Lathe Centers	Alox. Vit.	401-K-30	60 -M-28	80 -M-28
Leather				
Unhairing Machine (block)	Alox. Vit.		24 -D840	
Fleshing machine	Alox. Vit.		24 -D840	
Whitening machine...	Alox. Vit.		502-I + D845	70 -J-D842
Vaughn Shaving machine	Alox. Vit.		502-I + D845	70 -J-D842
Splitting machine ...	Alox. Shellac		30 -8-K8A	
	Alox. Redmanol		40 -14-K14T	
Leather				
Finishing or knapping chamols leather ...	Carbo. Vit.	16 -M-B3		
Sueding (drum wheel)	Carbo. Vit.	60 -M-B3		
Soles (Pounding machine)	Alox. Vit.	6 -K-J12		
Links				
Locomotive	Alox. Vit.	40 -H-D846	60 -H-D846	
Chain				
Malleable (annealed)	Alox. Vit.	24 -G-64		
Malleable (unannealed) ...	Carbo. Vit.	16 -F-MC11	24 -F-MC11	
	Alox. Vit.		30 -E-66	
Steel	Alox. Vit.	24 -G-64		
Machine Shop				
Cut off	Alox. Rubber	16 -KBR	24 -KCR	36-KCR
	Alox. Redmanol	50K-4	50K-6	70K-4
General Purpose	Alox. Vit.	16 -G-34	20 -H-33	36-I-32
		16 -G-64	20 -G-64	
Malleable Iron				
Annealed	Alox. Rubber	10-KDH	14 -KDH	
	Alox. Vit.	14-G-64	14 -H-63	16-H-63
Unannealed	Carbo. Vit.	14 -G + VA	16 -G + VA	20 -G + VA
	Carbo. Vit.	14 -G + MC10	16 -G + MC10	20 -G + MC10
	Alox. Vit.	16 -F-65	16 -G-64	20 -G-64
Marble and Stone				
Coping	Carbo. Redmanol	201-7-K7R		
	Carbo. Shel.	141-2-A3M	201-2-A3M	
Snagging and roughing	Carbo. Vit.	6-S-JH	10-S-JH	
Forming mould:				
Marble	Carbo. Vit.	40 -M-G3		
Sandstone	Carbo. Vit.	24-M-G8	40 -M-G3	
Honing	Carbo. Shel.		1803-I-C6F	

GRINDING WHEELS

Class of Work	Abrasive Material	GRADINGS		
		Coarse Hard	Medium Medium	Fine Soft
Polishing edges of marble (Pollard 14-16-18" dia.)	Carbo. Shel.		1803-1-C6F	
Turning Balusters & Columns (Granite and Sandstone)				
Roughing	Carbo. Vit.	6-S-JH		
Finishing	Carbo. Vit.	40 -M-G3		
Limestone	Carbo. Vit.	24 -M-G3	40 -M-G3	
Marble	Carbo. Vit.		40 -M-G3	
Artificial Stone	Carbo. Vit.	24 -M-G3		
Carbo & Alox. rubs for Marble, granite, slate, Rough & coarse grit-ting	Carbo. Vit.	40 -M-G3	80 -M-G3	
Fine	Carbo. Vit.	120-M-G3		
	Alox. Vit.		1535	
	Alox. Vit.		1833	
Honing	Carbo. Shel.	220-1-C6F	F -1-C6F	2F-1-C6F
Honing (slate)	Carbo. Shel.		F -1-RDC	2F-1-RDC
Metallographic Specimens				
Roughing	Carbo. Vit.	60 -P-GP		
Finishing	Carbo. Vit.		120-P-GP	2F-K-G4
Milling Cutters (See Cutters)				
Monel Metal				
Roughing	Alox. Vit.	16 -G-64		
Cut off	Alox. Rubber	16-KBR		
	Alox.			
	Redmanol		50K-4V	50K-4
Needles				
Phonograph	Alox. Vit.	401-H-D846	150-J-31	150-J-D940
Knitting	Alox. Vit.	80 -H-D846		
Pointing	Alox. Vit.	80 -H-D846	150-H-33	150-H-942
	Alox. Rubber			80 -KD
Pearl				
Hand Roughing	Carbo. Vit.	40 -H-G7	80 -H-G7	
Hand Finishing	Carbo. Vit.			120-G-G10
Buttons—automatic ..	Carbo. Vit.	30 -H-B8		
		36 -H-G7	40 -L-G3+	
Turning Tools (Sharpening)	Alox. Vit.		80 -I-D844	80 -I-32
Pearl Novelties, to 4" dia.	Carbo. Vit.	100-H-G9	150-H-G9	220-H-G9
Pins	Alox. Vit.	80 -H-33	150-G-34	150-G-D944
Pipe				
Cut off	Alox. Rubber	16 -KBR		
	Alox.			
	Redmanol		50K-4V	

THE ABRASIVE HANDBOOK

Class of Work	Abrasive Material	GRADINGS		
		Coarse Hard	Medium Medium	Fine Soft
Internal (see cast iron)				
Pipe Balls				
Cylindrical				
Between Centers ...	Alox. Vit.	246-J-31	301-J-31	
Centerless	Alox. Vit.	30 -G-64		
Pistons				
Aluminum Alloy				
(auto)	Carbo. Vit.	403-P-CF		
	Alox. Vit.	401-O-26		
Cast iron (Between centers)	Carbo. Vit.	36 -K-G4	36 -M-G3	365-M-B3
Cast iron (centerless) ..	Carbo. Vit.	36 -P-E1½		
Steel	Alox. Vit.	401-M-28		
Piston Pins (Wrist Pins)				
Cylindrical				
Between Centers ..	Alox. Vit.	401-K-30	401-M-28	60 -M-28
Centerless	Alox. Vit.	60 -J-31	60 -L-29	80 -K-30
	Alox. Rubber		80 -KDX	100-KDX
Piston Rings				
Cylindrical	Carbo. Vit.	36 -K-G4	36 -M-G3	
Surfacing (Horizontal)	Alox. Vit.	40 -M-D498	50 -N-27	
	Alox. LL	50 -M-L9	60 -R-L5	
Surfacing (Vertical) ..	Alox. LL	20 -P-L6	24 -P-L6	
Internal	Carbo. Vit.	24 -J-G5	36 -N-E2½	60 -J-G5
Piston Rods	Alox. Vit.	246-K-30	301-K-30	401-M-28
Plate Glass (see glass)				
Plows				
Chilled Iron:				
Surfacing	Carbo. Vit.	16 -G+VA	20 -G+VA	
	Alox. Vit.	20 -K-30	30 -L-29	
Jointing	Carbo. Vit.	16 -G+VA	20 -G+VA	
Fitting	Carbo. Vit.	16 -G+VA	20 -G+VA	
Steel:				
Surfacing (30" wheels)	Alox. Vit.	16 -H-33	16 -I-32	20 -H-33
Surfacing (20" wheels)	Alox. Vit.	16 -H-33	20 -H-33	
Jointing	Alox. Vit.	16 -G-34	20 -H-33	
Fitting	Alox. Vit.	24 -H-33		
	Alox. Rubber	16 -KDR		
Re-sharpening plow points	Alox. Vit.	20 -G-64	24 -H-33	30 -H-33
Porcelain				
Cut-off tubing	Carbo.			
	Redmanol	50C-4	70C-4	
Roughing	Carbo. Vit.	40 -H-G7	60 -J-G5	
Finishing	Carbo. Vit.		80 -J-G5	
Surfacing (ring wheel)	Carbo. Vit.	16-P-E1½	16 -R-E1	
Pulleys				
Crowning (cylindrical)	Carbo. Vit.	24 -K-G4	36 -M-G3	

GRINDING WHEELS

Class of Work	Abrasive Material	GRADINGS		
		Coarse Hard	Medium Medium	Fine Soft
Rails				
Surfacing	Alox. Vit.	12 -G-64	14 -H-63	
Blocks	Alox. Vit.	16 -K-J12		
	Alox. Vit.	16 -I-32		
Welds—surfacing	Alox. Vit.	24 -H-63	36 -H-33	
Razors, Safety				
Sharpening	Alox.			
	Redmanol	180-10-K10R		
	Alox. Rubber	220-KE		
	Alox. Shellac			3F-3-K3A
Re-sharpening	Alox. Vit.	60M-H-D943		
Reamers				
Backing off	Alox. Vit.	301-K-30	401-M-28	60 -M-28
Cylindrical	Alox. Vit.	301-K-30	401-M-28	60 -M-28
	Alox. LL	36 -N-L8	40 -N-L8	50 -N-L8
Fluting	Alox. Rubber	36-KCR	50 -KCR	70 -KCR
Rims (Automobile)				
Welds	Alox. Vit.	20 -F-35	20 -G-34	24 -H-33
	Alox. Rubber	20 -KBL		
Roller Bearing Cups				
Centerless	Alox. Vit.	60 -M-28	60 -O-26	60 -R-24
Cylindrical	Alox. Vit.	401-M-28	401-O-26	60 -P-25
Internal	Alox. Vit.	50 -L-D840	60-M-D498	60 -O-D496
	Alox. Vit.	50 -K-30	60 -L-29	60 -N-27
Rollers for Bearings				
Centerless	Alox. Vit.	60 -H-33	60 -J-31	80 -I-32
Cylindrical	Alox. Vit.	60 -G-34		100-I-D844
				100-H-33
Rolls				
Hardened Steel:				
Roughing	Alox. Vit.	246-M-D498	301-K-30	
	Alox.			
	Redmanol	24 -12-K12R	36 -12-K12R	
Finishing	Alox. Shellac		50 -5-K5A	120-7-K7A
Polishing	Carbo. Vit.			3F-Q-WF
	Carbo. Shel.			3F-5-C5A
Cast Iron:				
Roughing	Carbo. Vit.	24 -K-G4		
Finishing	Carbo. Vit.	36 -M-G3	60 -P-CF	
	Carbo.			
	Redmanol	36 -12-C12R		
Brass:				
Roughing	Carbo. Vit.	36 -M-G3	60 -P-CF	
	Carbo.			
	Redmanol	36 -12-C12R		
Finishing	Carbo. Shel.		40 -3-C3A	70 -3-C3A
Chilled Iron:				
Roughing	Carbo. Vit.	24 -K-G4	30 -K-G4	36 -M-G3
	Carbo.			
	Redmanol	20 -9-C9T	24 -10-C10R	36 -12-C12R
Finishing	Carbo. Vit.	36 -M-G3	403-P-CF	
	Carbo. Shel.	30 -2-C2B	40 -3-C3A	80 -4-C4A
			60 -4-C4A	

THE ABRASIVE HANDBOOK

Class of Work	Abrasive Material	GRADINGS		
		Coarse Hard	Medium Medium	Fine Soft
Jewelers' Rolls				
Roughing	Carbo. Vit.		60 -M-G3	
Finishing	Carbo. Vit. Alox. Shellac			3F-Q-WF 3F-4-K4A
Rubber Rolls				
Roughing	Carbo. Vit.	30 -M-G3	30 -P-CF	
Finishing	Carbo. Vit. Carbo. Shel.		60 -M-G3	80 -3-C3A
Copper:				
Roughing	Carbo. Shel.	80 -5-C5A		
Finishing	Carbo. Vit.		90 -S-WH	120-S-WH
Sad Irons				
Snagging	Carbo. Vit.	24 -H+HD	24 -J-G5	60 -G-G8
Surfacing	Carbo. Vit.	24 -M-E3	24 -P-D5L	
Safes				
External	Alox. Vit.	24 -K-30		
External (doors)	Alox. Vit.	30 -J-31		
Internal (holes)	Alox. Vit.	24 -J-31	30 -M-28	
Pit Grinding (internal)	Alox. Vit.	24 -J-31	30 -M-28	
Fitting	Alox. Vit.	24 -J-31	30 -M-28	
Surfacing	Alox. Vit.	24 -J-31	24 -L-29	
Snagging	Alox. Vit.	14 -H-33	16 -H-33	20 -H-33
Sand Cores				
Cut off	Carbo Rubber Carbo. Redmanol	24 -CBR 24C-2D		
Pointing	Carbo. Vit.		30 H+HD	
Saws (Gumming)				
Hand	Alox. Vit. Alox. Shellac Alox. Redmanol	365-K-D841 24-4 36-9-K9R 365-K-D841	365-L-D840 30 -4 40 -10-K10R 365-L-D840	403-K-D841
Circular	Alox. Vit. Alox. Redmanol	36-9-K9R 365-K-D841 36-9-K9R	40 -10-K10R	60 -M-D498
Metal Cutting	Alox. Redmanol Alox. Rubber Alox. Vit.	70K-4T 150-KFG 36 -M-28		60 -G-D847
Slate Saws				
Shears				
Hand Surfacing	Alox. Sil.	50 -J-SJ		90 -K-SK
Shovels				
Edging	Alox. Vit.	20 -F-D1189		30 -E-66
Skates				
Surfacing	Alox. Redmanol	50 -12-K12T 40 -K-D841	60 -12-K12T 60 -K-D841 80 -K-G4	80 -K-D841 120-K-G4
Re-sharpening	Alox. Vit. Carbo. Vit.			
Slate				
Surfacing	Carbo. Vit.	40 -M-G3		

GRINDING WHEELS

Class of Work	Abrasive Material	GRADINGS		
		Coarse Hard	Medium Medium	Fine Soft
Coping	Carbo. Shel.	141-2-A3M	161-2-A3M	201-2-A3M
Finishing (blocks) ..	Carbo. Shel.		220-1-RDC	F-1-RDC
Spline Shafts				
Cylindrical	Alox. Vit.	401-I-32	401-K-30	
Grinding Splines	Alox. Vit.	50-M-28	50 -P-25	
	Alox. AA	46A-M-681	46A-P-678	
Springs				
Coll (squaring ends) ..	Alox. Vit.	16S-G-34	20S-I-32	20S-J-31
Leaf:				
Surfacing	Alox. Vit.	24 -H-33	30 -H-33	
		24 -H-63	30 -H-63	
Chamfering	Alox. Vit.	24 -H-63		
Grinding Eyes	Alox. Vit.	16S-G-34	20S-I-32	30 -J-31
Steel				
Low Carbon				
Cylindrical	Alox. Vit.	301-I-32	301-K-30	301-M-28
	Alox. Vit.	246-K-30	246-M-28	
	Alox. Vit.	401-K-30	401-M-28	401 -O-26
	Alox. Vit.		60 -M-28	60 -P-25
Internal	Alox. Vit.	50 -L-D840	60 -M-D498	60 -O-D496
	Alox. Vit.	50 -K-30	60 -M-28	60 -O-26
Surfacing				
(horizontal)	Alox. LL	36 -P-L6	40 -P-L6	50 -R-L5
Surfacing (vertical)	Alox. LL	24 -P-L6	24 -S-L4	30 -T-L3
High Carbon:				
Cylindrical	Alox. Vit.	301-K-30	301-M-28	
	Alox. Vit.	246-M-28	246-P-25	
	Alox. Vit.	401-M-28	401 -O-26	401-P-25
	Alox. Vit.		60 -M-28	60 -P-25
Internal	Alox. Vit.	50 -L-D840	60 -M-D498	60 -O-D496
	Alox. Vit.	50 -K-30	60 -M-28	60 -O-26
	Alox. AA	46A-N-680	54A-P-678	60A-R-604
Surfacing				
(horizontal)	Alox. AA	36A-P-678	36A-T-604	46A-U-603
Surfacing (vertical)	Alox. LL	24 -R-L5	24 -T-L3	30 -U-L2
	Alox. Silicate AA	24 -R-SRAA	30 -S-SSAA	46A-U-SUAA
Steel Castings				
Snagging swing frame	Alox. Vit.	10 -G-64	12 -G-64	14 -H-63
Snagging floor stand.	Alox. Vit.	10 -H-63	12 -H-63	14 -I-32
Snagging portable ...	Alox. Vit.	20 -F-65	20 -G-64	20 -H-63
	Alox. Vit.	24 -G-64	24 -H-63	30 -H-63
Manganese Steel:				
Snagging swing				
frame	Alox. Vit.	12 -G-64	14 -H-63	16 -H-63
Snagging floor stand	Alox. Vit.	12 -G-64	12 -H-63	14 -H-63
Stellite				
Surfacing (horizontal)	Alox. Vit.	40 -R-24	60 -T-22	
Surfacing (vertical) ..	Alox. Sil	366-U-SU	501-V-SV	
Cut off	Alox.			
	Redmanol	50K-6	50K-8	80K-4V
Internal	Alox. Vit.	60 -O-26	80 -P-25	

THE ABRASIVE HANDBOOK

Class of Work	Abrasive Material	GRADINGS		
		Coarse Hard	Medium Medium	Fine Soft
Tools (off hand)				
Light cuts	Alox. Vit.	24 -H-33	36 -H-33	50-J-31
Heavy cuts	Alox. Vit.	40 O-26	50 -P-25	
Stove Parts				
Snagging	Carbo. Vit.	20 -G+VA	24 -G+VA	30 -G+VA
Fitting	Carbo. Vit.	206-G+VA		
	Alox. Vit.	301-E-66		
Notching	Carbo Rubber	16 -CBA	24 -CBA	
Grinding holes	Carbo. Vit.	24 -G+VA	30 -G+VA	
Surfacing:				
Roughing	Carbo. Vit.	36 -H-G7	40 -H-G7	80 -I-G6
Finishing	Carbo. Vit.		60 -H-G7	
Taps				
Fluting	Alox. Rubber	36 -KCR	60 -KCR	70 -KCR
Sharpening	Alox. Vit.	40 -N-D497	50 -L-D840	
Tile (Hollow)	Carbo. Vit.	24 -J-G5	36 -N-G2	40 -M-G3
Tubing				
Weld on Seamless	Alox. Vit.	16 -H-63	36 -H-33	
Cut off:				
Hard brass, bronze	Alox.			
	Redmanol	50K-4	50K-6	70K-4
	Alox. Rubber	16 -KBR	24 -KCR	36 -KCR
Soft brass,				
aluminum, carbon	Carbo.			
	Redmanol	50C-4	50C-6	70C-4
	Carbo Rubber	16 -CBR	24 -CBR	36 -CBR
Tools				
Lathe and Planer:				
Light	Alox. Vit.	36 -I-D844	50 -J-D842	60-J-D842
Heavy	Alox. Vit.	24 -H-D845	36 -H-D846	40 -I-D844
	Alox. Vit.	24 -H-63	36 -H-63	
Large wheels	Alox. Vit.	24 -H-D845	24 -L-29	30 -K-30
	Alox. Vit.	24 -H-63		
Cup wheels	Alox. Vit.		24 -K-30	24 -L-29
Tungsten Rods				
Cut off	Alox. Rubber	80 -KBR	100-KBR	
Valves (Auto)				
Seats	Alox. Vit.	60 -J-D842	80 -K-D841	
		60 -I-32	80 -J-31	
Stems-cylindrical	Alox. Vit.	401-K-30	401-M-28	
Centerless	Alox. Vit.	60 -J-31	80 -J-31	
Vitreous Ware				
Surfacing	Carbo. Vit.	36 -M-G3		
	Alox. Sil.	36 -N-SN		
Worms				
Thread Grinding	Alox. AA	46A-K-683	46A-M-681	
Wrenches				
Snagging	Alox. Vit.	24 -F-65	24 -G-64	30 -F-65
Surfacing	Alox. Vit.	24 -K-30	24 -M-28	30 -J-31

GRINDING WHEELS

The Norton Co. grit and grade recommendations for various classes of work are given in the following pages. Since the Carborundum and Norton grade scales run opposite, the two series of tables are necessary. Crys. is crystolon; alun., alundum; vit., vitrified; sil., silicate; rub., rubber; shel., shellac; bak., bakelite.

The numerals "19" placed before the grain number as "1950-M" indicate that the wheel is made of "19 alundum" abrasive. The numerals "38" placed before the grain number as "3850-M" indicate that the wheel is made of "38 alundum" abrasive. The letter "V" placed before the word "shellac" or the grade number designates a particular type of shellac bonded wheel. The letter "T" before the word "bakelite" or the grade number indicates a particular type of bakelite bonded wheel.

Grinding wheels are sometimes made of a combination of grains and are designated as, for example, 24 combination. A combination wheel with a mixture of fine, coarse, and medium grain sizes has a different cutting action from a straight-grained wheel and is desirable for certain operations, particularly cylindrical grinding. Such wheels are designated by 24C as 24C-K. Where the term "cylindrical" is used in the table, reference is intended to cylindrically grinding work on centers. By the word "centerless" is meant the production of work on a centerless grinding machine.

A grain and grade list such as this reaches its maximum usefulness only after its purpose is familiar to the user. It is impossible to recommend at all times the best wheel for a given operation because the grinding action depends not only upon the wheel structure itself but also on the wheel speed, size of wheel, size of work, condition of machine and, to a very large extent, on the way the wheel is handled by the operator.

In this table we have listed many of the common grinding operations. The column "First selection" list wheels that should be tried first. In the next column the usual range of wheels is given. Under ordinary operating conditions it will seldom be found necessary to use a wheel outside of this range. In making these recommendations we have taken it for granted that the wheel speeds are in agreement with those in the table on page 6, that the wheels are of a size commonly used for the work, and that the machines are in good operating condition.

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Work and Operation	Abrasive & Process	1st Selection Grain-Grade	Coarsest Hardest	Finest Softest
Agate				
Offhand roughing	Crys. Vit.	80 K	80-K	120-I
Offhand finishing	Crys. Vit.	240 J		
Aluminum				
Cylindrical	Crys. Vit.	40 J	30-K	40-J
	Alun. Shel.		30-3	36-3
Surface (Cups & Cyls.)	Alun. Vit.	3824 I	3820-J	3824-H
	Crys. Vit.		16-I	16-I
Internal Snagging	Crys. Shel.	30 1½		
	Alun. Shel.	36 5	30-6	46-4
	Crys. Shel.		30-6	46-4
	Crys. Vit.		24-R	36-0
Armatures (Laminations)				
Cylindrical	Alun. Vit.	36 I	30-J	36-I
Artificial Stone (See Stone)				
Axes (Soft Steel)				
Siding	Alun. Vit.	36 R	30-R	36-Q
Edging	Alun. Vit.	20 U	20-U	30-S
Axes (Auto)				
Cylindrical	Alun. Vit.	46 L	46-L	46-K
	Alun. Vit.		24C-L	24C-K
Axes (Railway)				
Cylindrical	Alun. Vit.	46 L	46-L	46-K
	Alun. Vit.		24C-L	24C-K
Balls (Soft—Large)				
Roughing	Alun. Vit.	36 Z	36-Z	60-W
Balls (Soft—Small)				
Roughing	Alun. Vit.	60 Z	60-Z	120-Z
Balls (Hard or Soft—Large)				
1st Finishing	Alun. Vit.	80 Z		
Balls (Hard or Soft—Small)				
1st Finishing	Alun. Vit.	180 Z		
Balls (Hard—Large)				
Final Finishing	Alun. Vit.	XF Z		
Balls (Hard—Small)				
Final Finishing	Crys. Vit.	XF Z		
Ball Races—Radial (Soft Steel)				
Rough Surfacing (Cyls. & Cups)	Alun. Sil.	3820 J	3816-J	3824-H
	Alun. Sil.		1936-I	1946-K
Ball Races—Radial (Hardened Steel)				
Finish Surfacing (Cups and Cyls.)	Alun. Sil.	3830 G	3824-H	3836-G
	Alun. Vit.		3846-G	3846-G
Cylindrical	Alun. Vit.	1946 K	1936-L	1950-K
	Alun. Vit.		1924C-L	1924C-K
Rough Grooving (Inner Race)	Alun. Vit.	1970 K	1946-M	1980-L
Finish Grooving (Inner Race)	Alun. Shel.	120 4	80-5	150-2½
	Alun. Vit.		1950-N	1970-K
Rough and Finish Grooving (Inner Race, One Operation)	Alun. Shel.	80 4	46-5	90-2½
Rough Grooving (Outer Race)	Alun. Vit.	1970 K	1936-L	1970-J
Finish Grooving (Outer Race)	Alun. Shel.	120 4	80-5	180-2½
Rough and Finish Grooving (Outer Race)	Alun. Bak.		70-8	150-3
Internal	Alun. Vit.	90 5	1946-M	1970-K
		1060 K		

GRINDING WHEELS

Work and Operation	Abrasive & Process	1st Selection Grain-Grade	Coarsest Hardest	Finest Softest
Ball Races—Thrust (Hardened)				
Surfacing (Cyl. & Cups)	Alun. Vit.	3830 J	3824-K	3846-J
Grooving	Alun. Vit.	1946 J	1936-K	1950-I
Bath Tubs	Alun. Rub.	36 R9	30-R9	46-R8
Snagging	Crys. Vit.	24 S	20-U	30-S
Billets (High Speed and High Carbon Steel)				
Cleaning (Swing frames)	Alun. Vit.	20 R	12-R	20-P
Cleaning (Flexible Shaft)	Alun. Vit.	24 Q	20-R	30-P
Cleaning (Centerless)	Alun. Vit.	46 O	46-P	60-M
Billets (Alloy Steel)				
Cleaning (Swing Frames)	Alun. Vit.	14 S	12-S	20-P
Cleaning (Flexible Shaft)	Alun. Vit.	24 Q	20-R	30-P
Bits (Auger)				
Grinding Throats	Alun. Rub.	36 R8	30-R8	36-R8
Fluting	Alun. Rub.	70 R8		
Bolts (Case-hardened Steel)				
Cylindrical	Alun. Vit.	60 L	60-N	60-L
Centerless	Alun. Vit.	80 M	60-O	80-M
Brake Shoes (Chilled Iron)				
Snagging	Crys. Vit.	24 S	16-U	24-S
Brass				
Cylindrical	Crys. Vit.	36 J	36-K	46-J
Internal	Crys. Vit.	36 J	36-K	46-I
Surfacing (Cups and Cyls.)	Crys. Vit.	24 H	24-J	30-H
Snagging	Crys. Vit.	24 Q	24-Q	30-P
Cutting-off	Crys. V-Shel.	36 V6	36-V7	50-V6
Brick (Vitrified)				
Snagging	Crys. Vit.	16 P	14-Q	16-N
Surfacing (Cups and Cyls.)	Crys. Vit.	20 M	16-N	24-M
Broaches				
Sharpening	Alun. Vit.	1946 K	1936-L	1950-K
	Alun. Vit.		3836-L	3850-K
Bronze (Soft) Use same wheels as for Brass				
Bronze (Hard)				
Cylindrical	Alun. Vit.	24C K	24C-M	24C-J
Internal	Alun. Vit.	3860 J	3836-K	3860-J
Snagging	Alun. Vit.	24 Q	16-R	30-P
Cutting-off	Alun. V-Shel.	36 V6	30-V7	46-V5
Buhr Stones				
Grooving (Narrow)	Crys. Rub.	46 R8	36-R8	60-R8
Grooving (Wide)	Crys. Vit.	24 M		
Bushings (Hardened Steel)				
Cylindrical	Alun. Vit.	46 K	30-L	46-J
Internal	Alun. Vit.	3846 K	3846-M	3880-J
Centerless (Roughing)	Alun. Vit.	60 L	46-N	80-K
Centerless (Finishing)	Alun. Rub.	120 R4		
Bushings (Cast Iron)				
Cylindrical	Crys. Vit.	36 J	30-L	36-J
Internal	Crys. Vit.	36 J	36-K	46-I
Buttons (See Pearl)				
Cams (Rough Forging)				
Roughing	Alun. Vit.	30 P	24-R	36-P
Cams (Hardened Steel)				
Finishing (Vitrified Wheels)	Alun. Vit.	3824C K	3824C-K	3824C-J
	Alun. Vit.		3846-K	3846-J
Finishing (Shellac Wheels)	Alun. Shel.	46 3	36-4	50-2

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Work and Operation	Abrasive & Process	1st Selection Grain-Grade		Coarsest Hardest	Finest Softest
Cam Rollers (Hardened Steel)					
Cylindrical	Alun. Vit.	3860	M	3846-N	3880-K
Internal	Alun. Vit.	3860	L	3850-M	3860-K
Cam Shaft Bearings					
Cylindrical	Alun. Vit.	24C	M	24C-M	60-K
Car Wheels (Chilled Iron)					
Cylindrical	Crys. Vit.	16	Q	16-R	24-P
Car Wheels (Steel)					
Cylindrical	Alun. Vit.	20	P	16-Q	24-N
Car Wheels (Manganese Steel)					
Cylindrical	Alun. Vit.	16	Q	14-R	16-Q
Carbon (Soft)					
Cutting-off	Crys. Rub.	16	R8	14-R8	30-R8
Carbon (Hard-Round-Small)					
Cutting-off	Crys. T-Bak.	46	T4		
Carbon (Hard-Round-Large)					
Cutting-off	Crys. Rub.	14	R8	14-R8	16-R8
Carbon (Hard-Plate)					
Stripping	Crys. T-Bak.	30	T5	36-T5	30-T4
Carbon (Metallic)					
Cutting-off	Crys. T-Bak.	30	T5	36-T5	30-T4
Carbon					
Surfacing	Crys. Vit.	30	J	30-J	46-I
Card Clothing					
Pointing Tips	Alun. Rub.	90	R8	80-R8	100-R8
Cylindrical	Alun. Vit.	12	L	12-K	12-M
Cast Iron					
Cutting-off	Crys. V-Shel.	36	V7		
Cylindrical	Crys. Vit.	36	J	30-L	36-J
Internal	Crys. Vit.	36	J	36-K	46-I
Surfacing (Cups and Cyls.)	Crys. Vit.	14	H	14-J	24-H
Surfacing (Straight Wheels)	Crys. Vit.	30	J	30-K	46-I
Snagging	Crys. Vit.	20	S	16-U	24-R
Chain Links (Malleable Iron and Steel)					
Snagging	Alun. Vit.	24	R	24-R	24-Q
Chain Links (Unannealed Malleable Iron)					
Snagging	Crys. Vit.	24	S	16-T	24-R
Chasers (Thread)					
Surfacing	Alun. Vit.	3846	J	3846-K	3846-J
Grinding Throats	Alun. Shel.	60	3		
Chilled Iron					
Snagging	Crys. Vit.	24	S	16-U	24-S
Surfacing (Cups and Cyls.)	Crys. Vit.	20	I	14-J	24-H
Surfacing (Straight Wheels)	Crys. Vit.	36	I	30-J	36-I
Cylindrical (See Rolls)					
Chisels					
Surfacing (Cups and Cyls.)	Alun. Shel.	46	5	46-V6	50-5
Edging (Cups and Cyls.)	Alun. Vit.	60	M	46-M	80-L
Sharpening	Alun. Vit.	46	M	46-N	50-M
Clay (Blocks)					
Surfacing (Cups and Cyls.)	Crys. Vit.	14	O	14-O	16-N
Surfacing (Segments)	Crys. Vit.	16	L	16-M	16-L

GRINDING WHEELS

Work and Operation	Abrasive & Process	1st Selection Grain-Grade	Coarsest Hardest	Finest Softest
Commutators				
Roughing (Wheels)	Crys. Shel.	46 2½		
Finishing (Wheels)	Alun. Shel.	80 2	46-2	46-2
Both Operations (Wheels)	Crys. Shel.			
Roughing (Bricks)	Alun. Shel.	60 3	80-2½	80-2½
Finishing (Bricks)	Crys. Shel.	80 2½		
	Alun. Shel.	120 1½		
Concrete				
Surfacing (Bricks by Hand)	Crys. Vit.	24 R	20-S	30-P
Surfacing (Bricks by Machine)	Crys. Vit.	24 Q	20-S	30-P
Surfacing (Cup Wheels)	Crys. Vit.	24 P	20-Q	30-N
Connecting Rods				
Internal	Alun. Vit.	3860 K	3860-L	3860-K
Surfacing (Cups and Cyls.)	Alun. Vit.	3830 I	3824-J	3830-H
Copper				
Cylindrical (also See Rolls)	Crys. Shel.	70 1½	60-2½	80-1½
Cutting-off	Crys. Rub.	24 R8	16-R8	30-R8
Surfacing (Cups and Cyls.)	Crys. Vit.	14 H	14-I	16-H
Couplers and Draw Bars				
Snagging	Alun. Vit.	10 T		
Crankshafts (Pins and Bearings)				
Roughing	Alun. Vit.	36 DR	36-DS	36-DO
Finishing	Alun. Vit.	50 DO	46-DP	50-DM
Snagging (for Balancing)	Alun. Vit.	20 R	16-R	24-P
Cut Glass (See Glass)				
Cutlery (See Knives)				
Cutters (Formed)				
(Gear)				
(Hob)				
(Inserted Tooth)				
(Milling)				
Sharpening (Machines)	Alun. Vit.	3846 K	3836-K	3860-J
	Alun. Vit.		1936-K	1960-J
Cutters (Molding)				
Sharpening (Offhand)	Alun. Vit.	46 M	46-P	60-M
Cylinders (Gas Engine)				
Internal (New Cyls., Wheels)	Crys. Vit.	36 H	30C-J	40-G
Regrinding (Wheels)	Crys. Vit.	36 H	30C-J	40-G
Honing (New Cyls., Sticks)	Crys. Vit.	180 M	150-O	240-K
Rehoning (Sticks, Roughing)	Crys. Vit.	60 L	60-M	60-K
Rehoning (Sticks, Finishing)	Crys. Vit.	180 M	150-O	240-K
Dies (Forging)				
Cleaning	Alun. Vit.	60 P	46-Q	60-O
Dies (Threading)				
Chamfering (Cone Wheel)	Alun. Vit.	80 P	80-Q	80-P
Dies (Drawing)				
Cleaning	Alun. Vit.	60 L	46-M	60-K
Surfacing (Cups and Cyls.)	Alun. Sil.	3824 I	3824-J	3830-H
Surfacing (Straight Wheels)	Alun. Vit.	3846 I	3836-K	3846-I
Drills				
Cutting-off	Alun. Bak.	46 5	36-6	46-3
	Alun. Shel.		46-5	60-4
Cylindrical	Alun. Vit.	50 N	46-N	60-M
Centerless (Roughing)	Alun. Vit.	80 L	46-M	80-K
(Finishing)	Alun. Rub.	120 R4	80-R6	150-R3
Precision Sharpening	Alun. Vit.	46 L	36-L	46-K
Point Thinning	Alun. Shel.	50 2	46-3	50-2

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Work and Operation	Abrasive & Process	1st Selection Grain-Grade	Coarsest Hardest	Finest Softest
Drills (Small)				
Fluting	Alun. Rub.	46 R8	46-R8	60-R8
Offhand Sharpening	Alun. Vit.	60 M	50-O	80-M
Drills (Large)				
Fluting	Alun. Vit.	46 P	46-R	60-P
Offhand Sharpening	Alun. Vit.	24 P	24-P	46-O
Files				
Surfacing	Alun. Sil.	1936 N	1930-O	1936-M
Forgings				
Snagging	Alun. Vit.	20 R	16-R	24-R
Fork Tines				
Offhand	Alun. Vit.	36 R	36-S	36-R
Frogs and Switches (Manganese Steel)				
Offhand Grooving (Portable Machines)	Alun. Vit. Alun. Rub.	20 R	16-R 16-R8	24-O 16-R8
Semi-Precision Grooving (Planer Type Machines)	Alun. Vit.	16 Q	14-S	16-Q
Snagging	Alun. Vit.	14 R	12-S	16-Q
Surfacing	Alun. Vit.	14 R	12-S	16-Q
Gages (Plug)				
Cylindrical	Alun. Vit. Alun. Vit.	3880 K	3860-K 1960-K	38100-J 19100-J
Gages (U. S. Thread, Coarse Pitch) Grinding Threads	Alun. Vit.	38120 K	38120-L	38120-K
Gages (U.S. Thread, Medium Pitch) Grinding Threads	Alun. Vit. Crys. Vit.	38200 K	38200-L 120-P	38200-K 150-L
Gages (U. S. Thread, Fine Pitch) Grinding Threads	Alun. Vit. Crys. Vit.	38200 M	38200-O 120-P	38200-M 150-L
Gears (Cast Iron)				
Cleaning between teeth (Offhand)	Crys. Rub.	36 R8	30-R8	60-R8
Gears (Hardened Steel)				
Form Precision Grinding	Alun. Vit.	3850 K	3846-M	3860-J
Generative Precision Grinding	Alun. Vit.	3860 J	3846-K	3860-J
Internal	Alun. Vit.	3846 K	3846-L	3860-J
Surfacing (Cups and Cyls.)	Alun. Vit.	3830 H	3824-I	3836-G
Surfacing (Straight Wheels)	Alun. Vit.	3850 I	3846-J 1946-J	3860-H 1960-H
Glass (Cut)				
Puntying (Concaving bottoms of Glasses and Tumblers)	Alun. Vit.	3890 K	3890-M	3890-K
Puntying (Beading, deep)	Norton Deep Mitre or Light Ware Stone			
Puntying (Beading, shallow)	Norton Fine Mitre Stone			
Puntying (Grapes on Rich Cut Glass)	Norton Deep or Medium Mitre Stone			
Puntying (Grapes on Light Ware)	Norton Light Ware Stone			
Puntying (Petals on Rich Cut Glass)	Norton Deep or Medium Mitre Stone			
Puntying (Petals on Light Ware)	Norton Light Ware Stone			
Edging (Rich Cut Glass)	Norton Medium Mitre Stone			
Edging (Light Ware)	Norton Light Ware Stone			
Engraving (Punties, Flat Leaves, etc.)	Norton Deep Mitre Stone			

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Work and Operation	Abrasive & Process	1st Selection Grain-Grade	Coarsest Hardest	Finest Softest
Glass (Cut)—Cont'd				
Engraving (Edge Cuts)	Norton Medium Mitre Stone			
Engraving (Fine Work)	Norton Fine Mitre Stone			
Fluting (Rich Cut Glass)	Norton Deep Mitre Stone			
Fluting (Light Ware)	Norton Light Ware Stone			
Scalloping (Rich Cut Glass)	Norton Deep Mitre Stone			
Smoothing and Flat Work (Rich Cut Glass)	Norton Deep Mitre Stone			
Glass (Lamp Shades)				
Grinding Edges	Crys. Vit.	90 K	80-L	100-J
Glass (Lenses)				
Edging	Alun. Vit.	200 M	180-N	200-M
	Crys. Vit.		240-O	240-O
Surfacing (Torics)	Alun. Vit.	100 N	60-O	150-M
Glass (Tubing)				
Cylindrical	Crys. Vit.	36 J	30-K	60-J
Internal	Crys. Vit.	60 H	46-I	80-H
Nicking	Crys. Vit.	180 S		
Glass (Tumblers)				
Edging	Alun. Vit.	150 M	120-O	180-L
	Crys. Vit.		120-O	150-L
Glass (Circular Mirrors)				
Rough Beveling (Automatic machine on face of wheel)	Crys. Vit.	90 I		
Rough and Final Beveling (Automatic machine on face of wheel)	Alun. Vit.	200 K	200-K	200-K
Glass (Windshield)				
Rounding Corners (Face of Wheel, Offhand)	Alun. Vit.	150 N		
Semi-Polishing Edges (Side of Wheel, Offhand)	Alun. Vit.	150 N		
Rounding Corners (Face of Wheel, Automatic)	Alun. Vit.	150 N		
Granite				
Coping	Crys. V-Shel.	14 V7	14-V7	16-V7
Surfacing	Crys. Vit.	40 L	40-M	36-K
Guide Bars				
Surfacing (Segments or Cylinders)	Alun. Vit.	16 M	14-M	20-K
Surfacing (Straight Wheels)	Alun. Vit.	24 J	20-K	30-J
Hammers (Claw)				
Grinding between claws	Alun. Rub.	46 R8	46-R8	60-R8
Neck Grinding	Alun. Vit.	30 P	24-Q	30-P
	Alun. Rub.	24 R8	24-R9	30-R8
	Alun. Vit.	30 P	24-P	36-O
All other Operations				
Housings (Auto Axle)				
Cylindrical	Alun. Vit.	24C M	24C-N	24C-L
Snagging	Alun. Vit.	14 R	14-R	16-Q
Surfacing (Segments)	Alun. Vit.	16 O	12-P	16-N
Knives (Butcher)				
Machine Surfacing	Alun. Shel.	50 4	46-5	60-4
Offhand Surfacing	Alun. Sil.	1980 K	1970-L	1990-K
Knives (Chipper and Barker)				
Sharpening	Alun. Sil.	1936 J	1930-K	1946-I
Knives (Hog)				
Sharpening	Alun. Sil.	1936 J	1930-K	1946-I
Knives (Leather Fleshing)				
Sharpening (Bricks)	Alun. Vit.	24 R	24-R	46-O

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Work and Operation	Abrasive & Process	1st Selection Grain-Grade	Coarsest Hardest	Finest Softest
Knives (Leather Shaving)				
Sharpening	Alun. Vit.	50 O	50-P	50-O
Knives (Leather Splitting)				
Sharpening	Alun. Shel.	30 1½	30-1½	36-1½
Knives (Moulding)				
Offhand Sharpening	Alun. Vit.	36 M	36-N	46-L
Knives (Machine)				
Sharpening	Alun. Sil.	1936 J	1930-K	1946-I
Knives (Paper)				
Sharpening	Alun. Sil.	1936 J	1930-K	1946-I
Knives (Pocket)				
Machine Surfacing	Alun. Shel.	60 V6	46-V6	60-4
Offhand Surfacing	Alun. Sil.	120 O	90-P	120-N
Knives (Section)				
Bevelling	Alun. Sil.	36 M	36-N	46-L
Surfacing Backs	Alun. Sil.	1936 I	1936-J	1946-I
Knives (Sugar Beet)				
Rooting	Alun. Shel.	46 5		
Knives (Table)				
Roughing	Alun. Shel.	46 5	46-5	70-3
Finishing	Alun. Shel.	100 3	70-3	100-3
Rough and Finish (One Operation)	Alun. Shel.	60 5	60-5	70-4
Bolster Grinding	Alun. Rub.	36 R8	36-R8	60-R8
Knives (Veneer)				
Sharpening	Alun. Sil.	1936 J	1930-K	1946-I
Links (Locomotive)				
Machine Grinding	Alun. Vit.	46 P	36-P	60-M
Links (Chain-Malleable Iron and Steel)				
Snagging	Alun. Vit.	24 R	24-R	24-Q
Links (Chain-Unannealed Malleable Iron)				
Snagging	Crys. Vit.	24 S	16-T	24-R
Machine Shop Grinding				
General Offhand	Alun. Vit.	24 Q	24-Q	30-O
Malleable Iron Annealed				
Snagging	Alun. Vit.	20 R	20-S	24-Q
	Alun. Rub.		12-R8	16-R8
Malleable Iron Unannealed				
Snagging	Crys. Vit.	20 S	16-S	20-R
Marble				
Balusters (Rough Turning)	Crys. Vit.	8 M	8-O	8-L
Balusters (Finish Turning)	Crys. Vit.	36 K	36-K	36-J
Coping	Crys. V-Shel.	14 V6	14-V7	20-V6
Surfacing (Segments)				
1st Gritting	Crys. Vit.	120 K		
2nd Gritting	Alun. Vit.	180 I	180-J	200-I
Honing	Alun. Shel.	XF 5	XF-5	XF-4
	Alun. Vit.		280-J	280-J
Surfacing (Wheel)				
Roughing	Crys. Vit.	8 L	8-M	8-K
Finishing	Crys. Vit.	36 J	24-L	46-J
Moulding				
Roughing	Crys. Vit.	8 L	8-M	8-K
Finishing	Crys. Vit.	36 J	24-L	46-J
Metallographic Specimens				
Roughing	Alun. Vit.	80 P		
Finishing	Alun. Vit.	200 M		
Monel Metal				
Cutting-off	Alun. Rub.	16 R8		
	Alun. Bak.	16 8		

GRINDING WHEELS

Work and Operation	Abrasive & Process	1st Selection Grain-Grade	Coarest Hardest	Finest Softest
Snagging	Alun. Vit.	24 Q	24-Q	24-R
Needles				
Pointing	Alun. Vit.	70 P	50-Q	70-P
Pearl				
Buttons (Backing)	Crys. Vit.	50 O	46-P	60-M
Buttons (Surfacing)	Crys. Vit.	36 O	36-P	46-N
Buttons (Roughing Rough Blanks)	Crys. Vit.	36 Q	30-R	36-N
Buttons (Slitting)	Crys. V-Shel.	80 V7		
Buttons (Grooving)	Crys. Vit.	150 S		
Buttons (Grinding Fish Eyes)	Crys. Vit.	150 T	120-U	150-T
Pins				
Pointing	Alun. Vit.	120 R	90-Z	200-R
Pipe (Soft Steel)				
Cutting-off	Alun. Shel.	46 5	46-V6	50-4
Internal	Alun. Vit.	20 P	16-Q	24-S
Pipe Balls (Manganese Steel)				
Cylindrical Machine				
Roughing	Alun. Vit.	36 N	24-Q	36-N
Regrinding	Alun. Vit.	46 M	46-N	46-M
Centerless Machine				
Roughing	Alun. Vit.	36 O		
Regrinding	Alun. Vit.	36 O	30-P	46-L
Pistons (Aluminum)				
Cylindrical	Crys. Vit.	36 J	36-L	40-J
	Alun. Shel.		36-2	36-2
Pistons (Cast Iron)				
Cylindrical	Crys. Vit.	36 K	36-L	46-J
Piston Pins				
Cylindrical Machine	Alun. Vit.	1960 L	1960-M	1960-K
	Alun. Vit.		3860-M	3860-K
Centerless Machine				
Roughing	Alun. Vit.	60 M	46-M	80-K
Finishing	Alun. Shel.	120 R4	120-R5	150-R3
Piston Rings (Cast Iron or Semi-Steel)				
Cylindrical	Crys. Vit.	36 K	30-M	36-K
Surfacing Roughing (cylinders)	Crys. Vit.	20 J	16-M	24-J
Surfacing (Straight Wheels)	Alun. Vit.	1950 N	1936-N	1950-L
Internal (Offhand)	Crys. Vit.	20 Q	16-R	20-Q
Piston Rods (Locomotive)				
Cylindrical	Alun. Vit.	24C L	24C-M	24C-K
Plows (Steel)				
Surfacing	Alun. Vit.	16 R	16-R	20-Q
Fitting	Alun. Vit.	20 R	20-S	24-Q
Edging and Jointing	Alun. Vit.	16 R	16-S	16-Q
Plows (Chilled Iron)				
Surfacing	Crys. Vit.	16 T	16-T	24-R
Edging and Jointing	Crys. Vit.	16 Q		
Fitting	Crys. Vit.	20 S	20-U	20-S
Porcelain				
Cutting-off	Crys. V-Shel.	30 V6	24-V7	36-V5
Cylindrical	Crys. Vit.	36 J		
Removing Imperfections	Crys. Vit.	150 S	120-T	180-O
Pulleys (Cast Iron)				
Cylindrical	Crys. Vit.	30 J	30-L	30-J
Rough with Pulley Grinder (Cylinder Wheel)	Crys. Vit.	24 I	16-L	24-I
Finish with Pulley Grinder (Cylinder Wheel)	Crys. Shel.	70 2	50-4	70-1½

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Work and Operation	Abrasive & Process	1st Selection Grain-Grade	Coarsest Hardest	Finest Softest
Rails (Welds)				
Surfacing	Alun. Vit.	20 O	16-O	24-O
Wheels	Alun. Vit.	24 N	20-P	24-N
Bricks				
Razors				
Burring	Alun. Vit.	46 O	46-P	46-O
Side of Tang	Alun. Vit.	60 N	46-O	80-N
Concaving	Alun. Vit.	60 O	60-O	70-M
Shoulders (Cutting in)	Alun. Vit.	80 P		
Shoulders (Shaping after Hardening)	Alun. Vit.	120 M	120-N	120-M
Edging (Roughing)	Alun. Vit.	3880 J		
Edging (Finishing)	Alun. Shel.	200 1½	200-2	XF-1½
Point Shaping	Alun. Vit.	46 O	46-P	60-N
Razors (Safety)				
Sharpening	Alun. Vit.	L897 J	L897-K	L897-J
Reamers				
Backing-off	Alun. Vit.	1946 K	1946-L	1950-J
Cylindrical	Alun. Vit.	1946 K	1946-L	1960-J
	Alun. Vit.		3846-L	3860-J
Fluting	Alun. Rub.	80 R8	60-R8	80-R8
	Alun. Bak.		46-9	60-7
Rifle Barrels				
Cylindrical	Alun. Vit.	1924C L	1924C-M	1924C-K
Rims (Automobile)				
Removing Welds	Alun. Vit.	24 Q	20-S	24-Q
Grooving	Alun. Rub.	30 R8	24-R8	30-R8
Roller Bearing Cups				
Cylindrical	Alun. Vit.	1960 J	1950-K	1960-J
Internal	Alun. Vit.	3860 K	3846-L	3880-J
Rollers for Bearings				
Cylindrical	Alun. Vit.	100 O	90-O	100-N
Rolls (Brass or Copper)				
Cylindrical (Roughing)	Crys. Shel.	46 2	36-3	46-2
Cylindrical (Finishing)	Crys. Vit.	100 I		
Rolls (Granite)				
Roughing	Crys. Vit.	16 K		
Finishing	Crys. Vit.	36 J		
Rolls (Cast Iron)				
Cylindrical (Roughing)	Crys. Vit.	30 K	30-L	36-K
Cylindrical (Finishing)	Crys. Vit.	80 J	60-K	80-J
Rolls (Chilled Iron)				
Farrell Type Machine				
Roughing	Crys. Vit.	36 L	24-M	36-K
Finishing	Alun. Shel.	70 1½	60-2	80-1½
Norton Type Machine				
Cylindrical (Hot Plate Rolls)	Crys. Vit.	24 K	24-L	30-K
Cylindrical (Dryer Rolls)	Crys. Vit.	46 J		
Cylindrical Rolls for Cold Rolling Steel	Crys. Vit.	80 J	60-K	80-I
Cylindrical (Polishing)	Crys. Shel.	XF I		
Rolls (Hard Rubber)				
Cylindrical (Roughing and Finishing)	Crys. Vit.	36 K	36-K	46-J
Rolls (Soft Rubber)				
Cylindrical (Roughing and Finishing)	Crys. Vit.	36 K		
Rolls (Steel, Hardened)				
Farrell Type Machine				
Roughing Machine	Alun. Vit.	46 L		
Finishing	Alun. Shel.	70 1½		
Norton Type Machine				

GRINDING WHEELS

Work and Operation	Abrasive & Process	1st Selection Grain-Grade	Coarsest Hardest	Finest Softest
Cylindrical	Alun. Vit.	3846 J		
Cylindrical (Polishing)	Crys. Shel.	XF 1	3846-K	3880-J
Roll Scouring (Bricks)				
(All types of rolls)	Crys. Vit.	60 O	46-P	150-M
Rubber (Soft)				
Cylindrical	Crys. Vit.	36 K		
Rubber (Hard)				
Cutting-off	Crys. Rub.	30 R8		
Cylindrical	Crys. Vit.	36 K	36-K	46-J
Sad Irons				
Surfacing (Cups and Cyls.)	Crys. Vit.	20 H	14-J	20-H
	Alun. Sil.		3814-I	3814-I
Surfacing (Offhand)	Crys. Vit.	16 N	16-N	20-L
Snagging	Crys. Vit.	16 Q	16-Q	24-P
Safes				
Snagging	Alun. Vit.	16 Q	14-R	16-O
Surfacing	Alun. Vit.	20 O	20-P	24-N
Sand Cores				
Cutting-off	Crys. Rub.	24 R8	20-R8	30-R8
Saws (Band)				
Gumming	Alun. Vit.	1946 M	1936-M	1950-L
	Alun. Shel.		30C-5	30C-4
Saws (Circular)				
Gumming	Alun. Vit.	1946 M	1936-N	1946-N
Saws (Metal Cutting)				
Gumming	Alun. Vit.	60 P	50-Q	80-P
Saws (Metal Slitting)				
Gumming	Alun. V-Shel.	80 V6	60-V7	80-V6
Backing-off	Alun. Vit.	1946 I	1946-J	1960-I
	Alun. Vit.		3846-I	3860-I
Scissors and Shears (Cast Iron)				
Surfacing Sides of Blades	Crys. Vit.	100 S		
Scissors and Shears (Steel)				
Surfacing sides of blades (Cyl.)	Alun. V-Shel.	150 V5		
Grinding Flash from Bows	Alun. Vit.	46 P	46-P	60-O
Pointing and Shaping	Alun. Vit.	50 O	50-O	60-O
Grinding Neck or Corner	Alun. Shel.	120 4		
Strike Cutting Edges	Alun. Vit.	120 M		
Resharpening	Alun. Vit.	38100 L		
Shovels				
Edging	Alun. Vit.	30 U	24-U	30-S
Slate				
Coping	Crys. Shel.	16 V6	16-V6	20-5
Spline Shafts				
Cylindrical	Alun. Vit.	1946 K	1946-N	1950-K
Surfacing Splines	Alun. Vit.	1946 K	1936-L	1950-J
Springs (Leaf)				
Grinding Eyes	Alun. Vit.	24 Q	16-R	24-O
Chamfering	Alun. Vit.	24 Q	24-R	30-Q
Springs (Coil)				
Squaring Ends	Alun. Vit.	24 Q	16-R	24-P
Steel Castings (Low Carbon)				
Snagging (Swing Frame)	Alun. Vit.	12 S	10-W	16-R
Snagging (Floor Stand)	Alun. Vit.	14 R	12-S	16-Q
Snagging (Small Bench Stand)	Alun. Vit.	24 Q	24-Q	36-Q
Snagging (Portable Machine)	Alun. Vit.	24 R	16-S	24-Q
Steel Castings (Manganese)				
(See also "Frogs and Switches")				

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Work and Operation	Abrasive & Process	1st Selection Grain-Grade	Coarsest Hardest	Finest Softest
Snagging (Swing Frame)	Alun. Vit.	14 R	14-U	16-Q
Snagging (Floor Stand)	Alun. Vit.	16 Q	14-T	20-P
Steel (Hardened)				
Cylindrical	Alun. Vit.	3824C K	3824C-L	3824C-J
	Alun. Vit.		1946-K	1946-J
Surfacing (Cups and Cyls.)	Alun. Sil.	3830 G	3824-I	3860-G
Surfacing (Straight Wheels)	Alun. Vit.	3836 H	3830-J	3846-H
Cutting-off	Alun. Bak.	46 4	46-4	60-3
	Alun. Shel.		46-5	60-4
Internal	Alun. Vit.	3860 J	3846-K	3860-H
	Alun. Vit.	60 DL	46-DN	60-DJ
Steel (Soft)				
Cylindrical	Alun. Vit.	24C M	24C-N	24C-L
	Alun. Vit.		46-N	46-L
Surfacing (Cups and Cyls.)	Alun. Vit.	3816 J	3816-K	3824-I
Surfacing (Straight Wheels)	Alun. Vit.	3836 K	3824-L	3836-J
Cutting-off	Alun. Rub.	36 R8	30-R8	36-R8
	Alun. Bak.		36-8	46-5
Internal Grinding	Alun. Vit.	3846 L	3836-N	3846-K
Steel (High Speed)				
Surfacing (Cups and Cyls.)	Alun. Sil.	3846 G	3830-H	3860-G
Surfacing (Straight Wheels)	Alun. Vit.	3846 G	3830-I	3846-G
Cutting-off	Alun. Shel.	60 4	46-5	60-4
	Alun. Bak.		46-3	60-3
Internal	Alun. Vit.	3846 J	3846-K	3860-H
Stellite				
Surfacing (Cups and Cyls.)	Alun. Sil.	3846 G	3836-G	3860-G
Surfacing (Straight Wheels)	Alun. Vit.	3846 G	3830-I	3846-G
Snagging	Alun. Vit.	30 O		
Cutting-off	Alun. Shel.	46 5	46-5	60-5
Offhand Tool Grinding	Alun. Vit.	46 M	36-O	60-L
Stone (Artificial)				
Surfacing	Crys. Vit.	40 L	40-L	36-K
Grooving	Crys. Rub.	36 R8	36-R8	36-R7
Stove Parts (Cast Iron)				
Snagging	Crys. Vit.	24 S	24-U	30-S
Fitting and Mounting	Crys. Vit.	30 S		
Notching	Alun. Rub.	24 R8		
Grinding Out Cover Holes	Crys. Vit.	30 U	24-U	30-S
Surfacing Tops Automatic Machine				
Roughing	Crys. Vit.	36 P	30-Q	36-P
Finishing	Crys. Vit.	80 P	60-R	80-P
Taps				
Squaring ends	Alun. Vit.	60 N	46-P	60-M
Grinding relief	Alun. Vit.	60 N	46-P	60-M
Fluting	Alun. Bak.	46 9	46-9	60-7
	Alun. Rub.		60-R8	70-R8
Threading	Alun. Vit.	38150 L	38120-M	38XF-K
Shanks (Cylindrical)	Alun. Vit.	3880 L	3846-N	3880-K
Threads—See "Gages"				
Thread Gages—See "Gages"				
Tile				
Cutting-off	Crys. Shel.	36 5	30-V6	46-5
Tools (Lathe and Planer)				
Light (Offhand)	Alun. Vit.	46 N	46-P	60-L
Heavy (Offhand)	Alun. Vit.	30 O	24-P	30-Q
Using Large Wheels	Alun. Sil.	24 P		
Automatic (Cup Wheel)	Alun. Vit.	24 L	24-N	30-L
Automatic (Straight Wheel)	Alun. Sil.	46 M		
Tubes (Steel)				
Cutting-off	Alun. Rub.	36 R8	36-R8	60-R8
Tungsten Rods				
Cutting-off	Alun. Rub.	90 R9		

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Work and Operation	Abrasive & Process	1st Selection Grain-Grade	Coarsest Hardest	Finest Softest
Valves (Automobile)				
Grinding Seats	Alun. Vit.	60 N	60-O	80-M
Cylindrical Grinding Stems	Alun. Vit.	46 M		
Valve Tappets				
Cylindrical	Alun. Vit.	46 L	46-M	60-L
	Alun. Vit.		1946-M	1946-L
Welds				
Cleaning	Alun. Vit.	24 Q	20-S	36-Q
Worms				
Grinding Threads	Alun. Vit.	3836 K	3824-M	3836-K
Wrenches				
Snagging	Alun. Vit.	24 Q	16-R	24-Q
Surfacing	Alun. Vit.	24 Q	20-Q	46-O
Wrought Iron				
Snagging	Alun. Vit.	20 R	16-Q	24-Q

The following general suggestions for the selection of rubber-bond wheels for various purposes was compiled by the New York Belting & Packing Co.:

Class of work	Grain
Agricultural implements	12 to 30
Aluminum castings	24 to 46
Auger bits	46 to 70
Car wheels, cast iron	12 to 24
Car wheels, chilled	12 to 24
Iron castings, small	20 to 36
Iron castings (large)	16 to 24
Chilled iron castings (small)	24 to 36
Chilled iron castings (large)	20 to 30
Cutlery	36 to 100
Dies, chilled iron	24 to 36
Dies, steel	30 to 60
Drop forgings	16 to 36
Edge tools	36 to 70
Hammers, cast steel	20 to 36
Hollow-ware	24 to 46
Malleable iron castings (large)	8 to 20
Malleable iron castings (small)	16 to 30
Plows, cast iron parts	12 to 24
Plows, wrought iron parts	16 to 30
Plows, steel parts	16 to 30
Plows, chilled iron parts	12 to 24
Reamers	36 to 60
Rolls, cast iron, roughing	12 to 24
Rolls, cast iron, finishing	54 to 60
Rolls, chilled iron, roughing	16 to 36
Rolls, chilled iron, finishing	46 to 70
Rubber, hard	30 to 60
Steel, mild	16 to 36
Steel, hardening	24 to 46
Steel castings (large)	8 to 16
Steel castings (small)	12 to 30
Structural steel	16 to 30
Stove castings	12 to 30
Twist drills	36 to 70
Wrought iron	16 to 30
Woodworking tools	36 to 60

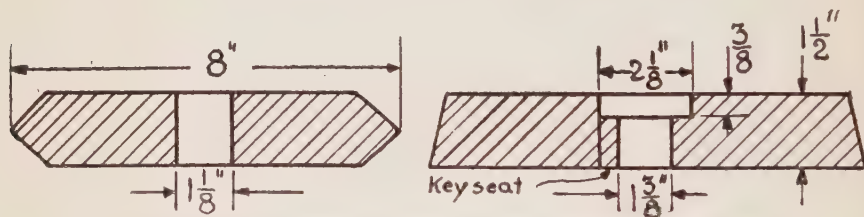
SHAVING MACHINE

In grinding wheel manufacturing parlance, a shaving machine is a modified form of potter's lathe on which grinding wheels are faced and bored. The wheel in the *green* state is located on a revolving table and the cutting tool is set in a holder that is mounted on a head which traverses over a cross rail. The head is adjustable so that straight or angular shapes can be shaved. The work is rotated by power but the down feed and the traversing movement are controlled by hand operated means.

SKILLET WHEELS

A name applied to special wheels used on a hollow ware grinding machine for finishing the insides of skillets or frying pans. Two popular types are shown below.

The wheel at the left is mounted on the end of an arbor in the usual way. In use one of the face angles is employed so



TWO TYPES OF SPECIAL WHEELS FOR FINISHING SKILLETS

that the wheel sides are at an angle of 45 degrees with the work. The wheel at the right is held in place by a key and a special screw that fits the countersunk depression.

SPECIAL WHEELS

Any grinding wheel that differs from the grinding wheel maker's standards is termed a special wheel. Thus a wheel 12 inches in diameter, 1 inch face, 5-inch hole, is a regular or standard shape wheel as it fits a Brown & Sharpe grinding machine and is carried in stock regularly by grinding wheel manufacturers. Assume, however, that such a wheel is ordered with a 4 3/16-inch hole. Such a wheel would be a special shape as it would have to be made up on a special order. When a grinding machine manufacturer designs a new machine with wheels different in size and shape from existing specifications,

GRINDING WHEELS

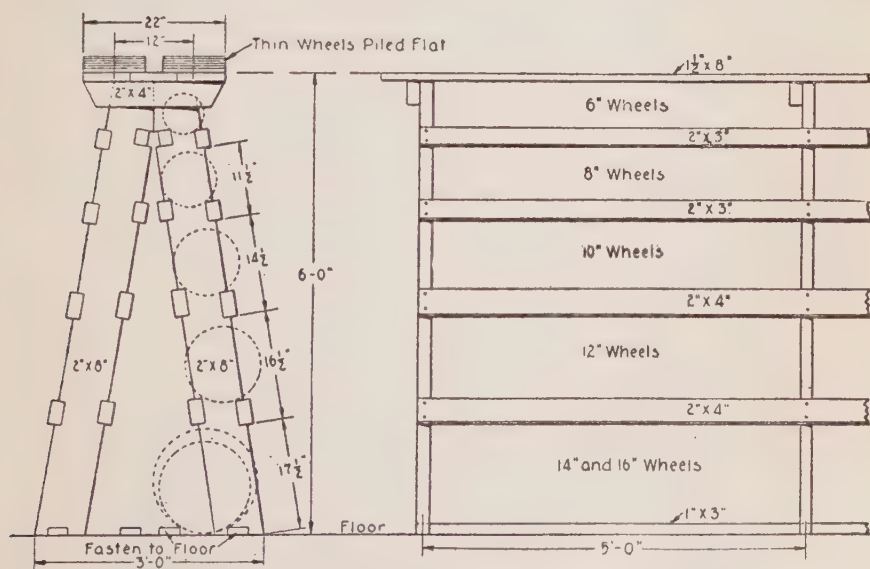
such wheels are special until they are recognized as standards.

Too much emphasis cannot be laid on the fact that grinding wheel consumers should endeavor to use standard equipment whenever possible. Some years ago, grinding wheel manufacturers were eager to make up wheels of special types in an attempt to gain new business. This practice, however, was much overdone. The grinding wheel salesman would sometimes convince the prospective customer that his work was of a different nature than any he heretofore had seen and that it was necessary to make up wheels of a *special mixture*. Today, however, grinding wheel manufacturers have come to realize that such a procedure is costly and confusing and in the present era of standardization the use of special wheels is being discouraged when possible.

In the design of new grinding machines, the manufacturer will do well to consult grinding wheel catalogs to see if it is not possible to use existing shapes instead of creating something new. Such a procedure is economical in the long run.

STORAGE OF GRINDING WHEELS

Upon receipt, all grinding wheels should be inspected to make sure that they have not been injured in transit. Then



CONVENIENT RACK FOR STORING GRINDING WHEELS

they should be stored in a clean, dry place. The wheels should be set on edge in racks, although shellac or rubber wheels less than $\frac{1}{4}$ -inch thick should be stored in piles to prevent warping. Small wheels, such as those used for internal grinding, can be kept in boxes or they can be strung on a wire. Both methods are used with good results.

The accompanying illustration shows a wheel storage rack designed by the Precision Grinding Wheel Co., Inc. While any kind of wood can be used in its construction, yellow pine is said to be preferable. The illustration is self-explanatory, as all the principal working dimensions are given. Such a rack can be made in any desired length.

TESTING WHEELS FOR EFFICIENCY

The efficiency of a grinding wheel depends on the cost of removing a given amount of metal in a stated time. Hard wheels are durable, but they cut slowly. Soft wheels cut rapidly, but they wear out prematurely. Thus a happy medium must be maintained. As far as grade influences efficiency it is a good plan to have the wheel just hard enough to require an occasional truing. The ideal wheel is one that wears away just enough to keep itself true. This condition, however, seldom is attained in everyday practice. The testing of grinding wheels for efficiency is not a difficult procedure, once the underlying principles are understood. Wheels used for rough grinding operations, such as snagging castings, can be tested readily where a run of work is had. Testing wheels on precision grinding machines is a more difficult procedure as a number of variables always are present. In general one of three methods can be followed in testing grinding wheels. They are as follows:

1—Use the wheel down to a stub and note how much metal is ground away while in service.

2—Use the wheel for a definite amount of time and compute the grinding cost by adding the cost of abrasive to the labor and overhead.

3—Grind a large piece of work, such as a steel mill roll, and add the abrasive cost to the labor and overhead cost.

In testing a wheel by the first method, the following factors must be given consideration: Wheel cost, payroll or labor cost, overhead, total cost, pounds of metal removed, and the cost per pound. This might work out as follows:

GRINDING WHEELS

Wheel cost	\$22.40
Labor cost, 80 hours	40.00
Overhead, 80 hours	40.00
Total cost	102.00
Pounds of metal removed	550
Cost of removing a pound	\$ 0.19

Let it be assumed that a more expensive wheel was tested. In this case the result might be as follows:

Wheel cost	\$30.00
Labor cost, 50 hours	25.00
Overhead, 50 hours	25.00
Total cost	80.00
Pounds of metal removed	475
Cost of removing a pound	\$ 0.168

Thus it is shown that some startling results are found in practical wheel tests. In this case the wheel that cost the most money reduced the actual grinding cost from 19 to less than 17 cents per pound.

In conducting a test by the second method the foregoing factors are used. In this case, however, the wheel cost is computed by weighing the wheel before and after use and computing the cost of the abrasive material used. This method is a handy one as it is not necessary to use the wheel up completely to carry out the test.

In carrying out a test by the third method, let it be assumed that a chilled iron roll 20 3/16 inches in diameter and 28 inches long was ground in four hours, removing 221 cubic inches of material. By computing the wheel wear the abrasive cost is ascertained. This added to the labor and overhead cost gives the total grinding cost.

In specific instances, the actual life of the wheel only is considered in an efficiency test. For example, in grinding the sprues from malleable iron chain links, the parts are fed past the wheel automatically. As the wheel and feed speeds are not changed the wheel that lasts the longest is the most efficient one. Again, the wheel used for sharpening leather splitting knives and leather shaving knives are tested for efficiency by noting how long they last, provided, of course, they cut satisfactorily the meanwhile.

In testing wheels for precision operations, more details are involved. This is especially true of cylindrical grinding as a number of variables must be considered in nearly every case. In many operations the cost of abrasive seems excessive. For

example, not many years ago it was customary to grind automotive engine crankshafts from the rough forgings, but with present-day production costs brought about by the war it is now thought to be a more economical procedure to turn the shafts first in special shaft lathes. This is common practice today. Data on wheel grinding costs varies from time to time and from shop to shop. As time goes on abrasive practices are bound to be more standardized than they are at present, so that accurate cost figures can be obtained more readily. It is difficult in many instances to obtain definite data as to the time that should be taken in carrying out a given grinding operation with given feeds and speeds, grits and grades. The wheel and work speeds often must be altered to obtain the necessary finish. What does in one shop will not answer in another. If it were possible to tell the grinding machine operator just what wheel to use, what grit and grade, wheel speed, work speed and traverse feed to employ, any cylindrical grinding job would be simple as far as testing wheels for efficiency is concerned. One wheel might be the base of an experiment and data computed on its performance for future reference. In using the next wheel of the same make, grit and grade the work speed might have to be altered to make the wheel cut properly. Again, as the wheel wears away its arc of contact becomes less and this injects a new factor into the test which may set the other data at naught. From the foregoing it is apparent that exact rules have yet to be formulated for testing wheels on cylindrical grinding machines for efficiency. Today, however, it is possible to arrive at very close approximations.

TESTING WHEELS FOR SAFETY

Many years ago the opinion was freely held that grinding wheels, or emery wheels as they then were termed, were very liable to burst. In the manufacture of present-day grinding wheels, however, every precaution is taken to make sure that none but sound wheels are shipped. In the average grinding wheel manufacturing plant, all wheels of six inches in diameter and over are given a speed test which consists of mounting them on a spindle enclosed in a stout oak box, and running them at nearly twice the recommended speed. This proves a factor of safety of at least $2\frac{1}{2}$. The testing machines are equipped

GRINDING WHEELS

with revolution counters so that the tester can note at all times the wheel speed.

A record of all tests is kept and the tester takes an oath daily before a notary public to the effect that all tests were pre-performed as recorded. None but careful and conscientious men are employed as testers and they proceed about their work with a certain amount of deliberation that precludes mistakes.

WEAR OF GRINDING WHEELS

In comparing the amount of metal removed to a given amount of abrasive material consumed, the nature of the work and the kind of abrasive used are governing factors. In general grinding and snagging one cubic inch of abrasive should remove from 20 to 25 cubic inches of metal. In cylindrical grinding, records made for this purpose show proportions ranging all the way from one cubic inch of wheel wear to four cubic inches of material removed to one cubic inch of wheel wear to 20 inches of material removed. The former wear is excessive and somewhere near the latter is about right. In the operation of its surface grinding machines, the Pratt & Whitney Co. state that a wheel in the correct grade should show a wear of from eight to 15 per cent of the amount of material removed.

In checking up wheels to ascertain the amount of wheel wear compared with the weight of the material removed the following methods can be used:

In ordinary rough grinding operations, first measure the wheel carefully and then operate it for a period of a day or two, the meanwhile weighing the castings before and after grinding to ascertain the amount of metal removed. At the end of the test measure the wheel again and compute the cubical contents that have been worn away. This is done as follows:

When the test is started the wheel can be considered as a cylinder and its volume or contents in cubic inches found by first finding the area of one side in square inches and multiply this by the thickness. Example, assume that the wheel is 24 inches in diameter and two inches thick—what is its volume in cubic inches?

To find the area multiply the square of the diameter by .7854. The square of the diameter is 24×24 or 576, which multiplied by .7854 gives 453.3904 inches as the area of the

wheel. Multiply this by the thickness of the wheel, 2 inches, and we get 906.7808 cubic inches as the volume of the wheel.

Assume that the wheel was used for two days and that in that time it was worn to a diameter of 23 inches. The contents of a wheel 23 inches in diameter and 2 inches thick is 830.9532 cubic inches. Subtracting this from 904.7808, the volume of the wheel when new, the wheel wear in round numbers is 74 cubic inches. Assume further that during the two days the wheel ground away 460 pounds of material, say cast iron. According to Kent, a cubic inch of cast iron weighs 0.2604 pounds and dividing 460 by .2604 it is found that the 460 pounds of material equal 1766 cubic inches.

In cylindrical grinding operations the wheel wear is ascertained by the method above described. Since the work is cylindrical also, the amount of metal removed is ascertained by measuring the amount removed on the diameter and then subtracting the cubical contents of the work as a cylinder from its volume when new.

The Pratt & Whitney Co. give the following method for computing wheel wear on surface grinding machines:

The work is placed on the magnetic chuck and the wheel is fed down a definite amount as the work passes under it. Then the work is removed from the chuck and is calipered with a micrometer. The difference between this reading and one taken before the piece was ground gives the amount of metal removed. The proportion of wear is ascertained by comparing the amount of metal removed with the amount the wheel is fed down during the operation, as shown by the micrometer dial on the feeding arrangement. For example, with a wheel feed of 0.4 inch the work should be reduced by 0.034 to 0.0386 inch if the wheel wear is from eight to 15 per cent of the amount of metal removed.

At the plant of one large producer of steel castings it was estimated that two to three cents worth of abrasive material was necessary to remove a pound of metal. In the case of wheels 18 inches in diameter x 3-inch face the wheels removed from 350 to 450 pounds of metal before they outlived their usefulness.

In the process of grinding the large chilled iron rolls used in steel mills it was shown by careful tests that 167 cubic inches

GRINDING WHEELS

of wheel material removed 1802 cubic inches of stock. In another test 113 cubic inches of wheel material removed 685 cubic inches of stock.

WEIGHTS OF GRINDING WHEELS

Frequently it is desirable to know the weights of grinding wheels of given sizes. To obtain the weight of a vitrified wheel made of an alumina abrasive—square its diameter, multiply by its thickness and divide by 15. To figure the weight of a carbide-of-silicon wheel subtract 7 per cent from the answer derived from the foregoing. To obtain the weight of silicate and elastic wheels use the foregoing formula and add 20 per cent to the result. The following table of wheel weights (vitrified) was compiled by the Abrasive Co.:

Wheel diam., in.	Thickness in inches									
	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{3}{4}$	1	$1\frac{1}{2}$	2	$2\frac{1}{2}$	3	4
3.....	0.14	0.22	0.27	0.40	0.56	0.85	1.14	1.40	1.70	.....
4.....	0.25	0.38	0.50	0.75	1.00	1.50	2.00	2.50	3.00	4.00
5.....	0.38	0.55	0.70	0.90	1.48	2.30	3.10	3.85	4.65	6.20
6.....	0.58	0.88	1.17	1.76	2.30	3.44	4.60	5.75	6.90	9.40
7.....	0.80	1.25	1.65	2.50	3.35	5.10	7.20	8.36	10.00	13.00
8.....	1.08	1.57	2.25	3.35	4.40	6.70	8.90	11.00	13.00	17.00
9.....	1.33	1.90	2.65	4.00	5.30	7.90	11.00	13.00	15.00	21.00
10.....	1.66	2.70	3.40	5.00	6.80	9.85	14.00	17.00	22.00	27.00
12.....	2.40	3.75	4.85	7.50	9.70	15.00	19.00	25.00	30.00	38.00
14.....	3.20	4.70	6.40	9.66	13.00	20.00	26.00	33.00	38.00	52.00
16.....	.....	6.12	8.15	12.00	17.00	26.00	34.00	43.00	51.00	68.00
18.....	.....	.....	11.00	16.00	22.00	33.00	44.00	55.00	66.00	87.00
20.....	.....	.....	.....	21.00	28.00	41.00	55.00	68.00	82.00	109.00
22.....	.....	.....	.....	.....	33.00	49.00	65.00	82.00	98.00	131.00
24.....	.....	.....	.....	.....	38.00	59.00	78.00	98.00	117.00	156.00
26.....	.....	.....	.....	.....	.....	69.00	92.00	115.00	138.00	184.00
30.....	.....	.....	.....	.....	.....	86.00	116.00	145.00	176.00	237.00
36.....	.....	.....	.....	.....	.....	127.00	177.00	221.00	265.00	354.00

WHEEL OPERATING SUGGESTIONS

The Safety Grinding Wheel & Machine Co., Springfield, O., gives the following suggestions for operating grinding wheels:

A constant periphery speed should be maintained as nearly as possible as the wheel wears down; in other words, the speed of the wheel spindle should be increased as the diameter of the wheel is decreased by wear. Complaints are sometimes made that wheels appear softer as they wear towards the center. This is caused by the wheel becoming smaller in diameter, and with the same spindle speed the periphery speed is reduced, thus causing the wheel to wear away faster and appear softer though in reality such is not the case.

The increase of the speed as the wheel wears away can be accomplished by different methods, that is, variable speed countershafts, cone pulleys on the spindle of the grinder or by transferring the wheels from the first grinder to smaller machines having higher speeds as the wheels wear down. This last system has decided advantages, and is highly recommended where there is sufficient grinding to warrant the use of more than one machine. These grinders should then have but one large pulley on the machine, which removes all the possibility of starting up the new wheel, with full diameter at the highest speed. When the single pulley system is not employed, great care should always be taken to start up the new wheel on the slow speed.

If on some particular work the wheel does not operate satisfactorily it can often be made to do so by changing the speed. If it fills or glazes, a slower speed will sometimes give better results, while if the kernels are being loosened by the work, a slight increase in speed (is not already running at the limit surface speed prescribed for that particular size wheel) will usually prolong the life of the wheel, and improve its cutting qualities.

When for any reason a wheel does not give entire satisfaction, discontinue its use immediately, and advise us of the difficulty, giving the particulars as far as possible, so that it can be exchanged for one that will be better adapted for the work. Great care should be taken to keep the wheels perfectly true and in balance to obtain the best results both as regards rapidity and accuracy in grinding. It is therefore necessary, for the sake of economy, that a dresser be kept constantly at hand to dress up the wheels the moment they become the least bit out of true. Often the wheel is allowed to get so far out that a great amount is wasted in bringing it back to the proper condition.

Never crowd a grinding wheel upon an arbor, and never mount wheels without flanges of some description. This warning may seem to a great many unnecessary, but we find wheels running, held simply by a small nut, which is apt to allow the wheel to crawl, and when forced may break the wheel. When tightening spindle end nuts, care should be taken to tighten same only enough to hold the wheel firmly, otherwise the clamping strain is liable to damage the wheel.

GRINDING WHEELS

The machine upon which the wheels are mounted should be heavy and strong, securely bolted to a firm foundation, thereby insuring safety and better results from the use of the wheels. Keep the boxes well oiled, so that the arbor will not become overheated, and, by expanding, break the wheel. We often find wheels that are running on machines that are entirely too light, and with the spindle and bearings worn out. Under such conditions it is impossible to suggest a proper or reasonably safe speed. Remember, that the condition of the machine has much to do with the efficiency of the operator.

Safety collars should always be used when possible. Both collars, whether straight or tapered, in contact with the wheels must be of the same diameter. It is not reasonable to expect that when a wheel has been furnished for a certain kind of work it will give as good results on other classes of work, so that too much ought not to be required of one grade of wheel; therefore, where the amount of grinding will warrant a variety of grades can profitably be employed, each carefully selected for its particular purpose. For instance, for grinding tools without drawing the temper requires a soft or medium grade of wheel, which would not be suitable for coarse, rough work, which would require a coarse grain and a harder grade. It is very necessary that the soft pads (paper, sheet rubber or leather), which are always shipped with the wheels, be used between the wheels and the collars. The rests for the work should always be kept in the best possible condition, and should be kept close to the wheel to keep the work from being caught, as this is one of the prevalent causes of grinding wheels breaking. Work should not be forced against a cold wheel, but applied gradually, giving the wheel an opportunity to warm and thereby eliminate possible breakage. This applies to starting work in the morning in grinding rooms which are not heated in winter, and new wheels which have been stored in a cold place. The rest should never be adjusted while wheel is running. Work should never be bumped or jammed against the wheel, as this does not make the wheel cut faster, and only increases the danger to those around it. A regular straight wheel of any make should never be run more than 5500 feet per minute.

WHEEL SPEEDS

As a general rule, a grinding wheel is operated at a peripheral speed of 5000 feet per minute, but this rule is open to a number of exceptions. To obtain the peripheral speed of a grinding wheel, multiply its diameter in inches by the constant 3.1416 which will give the circumference in inches. Then divide this product by 12 to obtain the wheel circumference in feet. Next multiply this result by the speed of the spindle in revolutions per minute which will give the peripheral travel in feet per minute. The following table of wheel circumferences is handy in making these calculations:

Diam. of wheel in inches	Circum. of wheel in feet	Diam. of wheel in inches	Circum. of wheel in feet	Diam. of wheel in inches	Circum. of wheel in feet
1.....	0.262	21.....	5.498	41.....	10.734
2.....	0.524	22.....	5.760	42.....	10.996
3.....	0.785	23.....	6.021	43.....	11.257
4.....	1.047	24.....	6.283	44.....	11.519
5.....	1.309	25.....	6.546	45.....	11.781
6.....	1.571	26.....	6.807	46.....	12.043
7.....	1.833	27.....	7.069	47.....	12.305
8.....	2.094	28.....	7.330	48.....	12.566
9.....	2.356	29.....	7.592	49.....	12.828
10.....	2.618	30.....	7.854	50.....	13.090
11.....	2.880	31.....	8.116	51.....	13.352
12.....	3.142	32.....	8.377	52.....	13.613
13.....	3.403	33.....	8.639	53.....	13.875
14.....	3.665	34.....	8.901	54.....	14.137
15.....	3.927	35.....	9.163	55.....	14.499
16.....	4.189	36.....	9.425	56.....	14.661
17.....	4.451	37.....	9.687	57.....	14.923
18.....	4.712	38.....	9.948	58.....	15.184
19.....	4.974	39.....	10.210	59.....	15.446
20.....	5.236	40.....	10.472	60.....	15.708

Grinding wheel speeds differ with the nature of the work, the type of machine, etc. The following data pertaining to wheel speeds, while general in character, will prove of value:

Application	Surface speed, feet per minute
Cylindrical grinding	5000 to 6500
Snagging and general offhand grinding.....	4500 to 5500
Wet tool grinding	3500 to 4500
Shellac and rubber wheels	7000 to 12500
Surface grinding, horizontal spindle machines.....	4000 to 5500
Surface grinding, vertical spindle machines.....	4000 to 5000
Knife grinding	3000 to 4000
Drill grinding	3500 to 4500
Cutlery grinding, Hemming machines	2000 to 4200

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The following table, compiled by the Manhattan Rubber Mfg. Co., gives peripheral speeds of grinding wheels in diameters from one to 30 inches in surface speeds from 4000 to 14,000 feet per minute:

		PERIPHERAL SPEED IN FEET PER MINUTE							
Diameter	Circumference	4,000	4,500	5,000	5,500	6,000	6,500	7,000	7,500
		REVOLUTIONS PER MINUTE							
inches	feet								
1.....	0.262	15,297	17,200	19,099	21,000	22,918	24,850	.....	.....
2.....	0.524	7,639	8,590	9,549	10,500	11,459	12,420	.....	.....
3.....	0.785	5,093	5,725	6,366	7,000	7,639	8,270	.....	.....
4.....	1.047	3,820	4,295	4,775	5,250	5,730	6,205	.....	.....
5.....	1.309	3,056	3,440	3,820	4,200	4,584	4,970	.....	.....
6.....	1.571	2,566	2,865	3,183	3,500	3,820	4,140	4,450	.....
7.....	1.833	2,183	2,455	2,728	3,000	3,274	3,550	3,813	4,085
8.....	2.094	1,910	2,150	2,387	2,635	2,865	3,100	3,342	3,581
10.....	2.618	1,528	1,720	1,910	2,100	2,292	2,485	2,673	2,865
12.....	3.142	1,273	1,453	1,592	1,750	1,910	2,070	2,228	2,387
14.....	3.665	1,091	1,228	1,364	1,500	1,637	1,773	1,910	2,047
16.....	4.189	955	1,075	1,194	1,314	1,432	1,552	1,671	1,790
18.....	4.712	849	957	1,061	1,167	1,273	1,380	1,482	1,590
20.....	5.236	764	860	955	1,050	1,146	1,244	1,336	1,431
22.....	5.760	694	782	868	952	1,042	1,128	1,215	1,302
24.....	6.283	637	716	796	876	955	1,035	1,114	1,194
26.....	6.807	586	661	733	809	879	955	1,028	1,102
28.....	7.330	546	614	683	749	819	887	955	1,023
30.....	7.854	509	573	637	700	764	827	891	956

		PERIPHERAL SPEED IN FEET PER MINUTE								
Diameter	Circumference	8,000	8,500	9,000	9,500	10,000	11,000	12,000	13,000	14,000
		REVOLUTIONS PER MINUTE								
inches	feet									
1...	0.262	....	....	....	....	....	....	....	....	....
2...	0.524	....	....	....	....	....	....	....	....	....
3...	0.785	....	....	....	....	....	....	....	....	....
4...	1.047	....	....	....	....	....	....	....	....	....
5...	1.309	....	....	....	....	....	....	....	....	....
6...	1.571	....	....	....	....	....	....	....	....	....
7...	1.833	4,360	....	....	....	....	....	....	....	....
8...	2.094	3,821	4,060	4,300	4,538	....	....	....	....	....
10...	2.618	3,056	3,247	3,438	3,728	3,820	4,202	....	....	....
12...	3.142	2,544	2,705	2,864	3,024	3,183	3,501	3,820	4,137	4,458
14...	3.665	2,183	2,320	2,456	2,592	2,728	3,000	3,274	3,547	3,820
16...	4.189	1,910	2,029	2,147	2,270	2,383	2,632	2,870	3,110	3,350
18...	4.712	1,695	1,800	1,907	2,014	2,120	2,333	2,548	2,758	2,970
20...	5.236	1,527	1,624	1,720	1,814	1,907	2,100	2,292	2,488	2,675
22...	5.760	1,389	1,476	1,563	1,650	1,737	1,910	2,083	2,256	2,430
24...	6.283	1,273	1,353	1,432	1,512	1,592	1,751	1,910	2,069	2,228
26...	6.807	1,175	1,249	1,322	1,395	1,469	1,616	1,763	1,910	2,058
28...	7.330	1,091	1,159	1,228	1,296	1,364	1,500	1,636	1,773	1,910
30...	7.854	1,021	1,086	1,151	1,216	1,281	1,412	1,543	1,674	1,804

WHEEL TRUING PRACTICE

Grinding wheels are trued and dressed with several types of tools, such as star wheel dressers of the Huntington type, chilled iron cutters, conical dressers, diamonds, special steel tools and abrasive devices. The foregoing types of tools all are used in regular shop practice with the exception of the conical dresser, which device is confined principally to grinding wheel manufacturing. It embodies a revolving steel cone that looks not unlike a small cup wheel. In use the cutting edge is brought against the wheel.

Wheels for rough grinding are trued with star-wheel dressers generally, although the chilled-iron cutters are used on comparatively large wheels. These devices are mounted in holders so that they can be guided past the wheel face by hand as they are held on the work rest. Usually the rest is moved a slight distance from the wheel so that the two claws on the yoke that holds the cutters can be brought against the work rest to aid in exerting pressure and guiding the tool in a straight line. Star-wheel dressers also give good results in truing wheels in cylindrical and surface grinding machines. In the former instance they are used for preparing wheel faces for rough grinding operations only. Diamonds, steel tools and abrasive devices are used principally for truing precision grinding wheels, although diamonds mounted in hand holders are employed for generating shaped wheels for various purposes.

In dressing wheels for precision work on cylindrical grinders with star-wheel dressers, the device must be clamped in place firmly and fed past the wheel with a fairly rapid motion. The sole object is to tear out the dull grains, exposing sharp ones. This operation in common with other wheel truing operations should be performed wet. The depth of cut for each pass usually is about 0.005-inch and it also is a good plan to employ the automatic table feed for traversing the tool.

In using wheel truing diamonds, great care must be exercised so that the stone will not be torn from its setting and lost. A slow automatic feed and plenty of cooling solution should be used. The depth of cut should be light, not over 0.001-inch. Several light cuts are better than a few heavy

GRINDING WHEELS

ones. A stone should not be used until it is worn nearly down to the setting, and for this reason the Joyce-Koebel gage shown below is an excellent device to employ. As the illustration shows, the diamond is mounted in a special nib provided with a groove that fits the gage. As long as the gage cannot be passed over the stone, all is well. When the stone has



GAGE FOR TESTING DIAMOND WEAR

worn to the extent of letting the gage pass over it, however, the nib should be turned in for resetting.

Various mechanical devices are used exactly the same as a diamond. That is, they are mounted in holders and fed past the wheel automatically. These are of two kinds. One employs an abrasive wheel which is located at an angle and fed past the wheel, while the other is provided with a metal roller. In both cases the wheel action causes the truing element to rotate. Mention also should be made of the Metcalf dresser which is an abrasive wheel used mounted between two globular handles. This device is used only for truing wheels for semi-precision operations. It is held by hand and fed past the wheel face at an angle.

Chatter and waviness in appearance of a finished part of cylindrical work are usually caused either by the wheel spindle being loose in its bearings, the grinding wheel out of true or out of balance, or particles of the material ground having become embedded in the wheel, according to the Landis Tool Co. In a great majority of cases, however, the cause of imperfect work is due to the wheel getting out of shape. It is important that the face of the wheel should be perfectly parallel with the travel of the carriage, and in order to secure this condition, a diamond tool must be used near the point where the grinding wheel comes in contact with the work, and on

small work close to the footstock center. Where the work is not so small, say two inches in diameter, the truing device can be clamped at the most convenient point, and in either case, care should be exercised so that the stud holding the diamond and the arm supporting same are held solidly against the work. If the truing device is not rigid, the grinding wheel will not be true.

It will be observed that the stud, in which the diamond is mounted, can be revolved in its holder, and it is important that the diamond point presented to the wheel should be sharp, for instance, if the diamond should become worn and flattened, it should be turned in its holder, and thus present a new point to the wheel. Keeping the wheel true is one of the important points for the operator to observe, particularly so when he comes to make a final finish. The wheel should be traversed by the diamond rapidly until it is true; the traverse should then be slowed down to give the wheel its final finish. If it is desired to do rapid cutting when roughing, it will be found proper to pass the wheel by the diamond rapidly, thus making a rougher face on the wheel.

The number of times the face of the grinding wheel has to be trued depends entirely on the character of work being finished and the kind of wheel used. There are some wheels that wear away rapidly enough so that little truing is necessary. There are also cases where a harder wheel is desirable, and a hard wheel necessarily requires more truing than a soft one. Where pieces are rather large and considerable stock has to be removed, it may be necessary to true the wheel each time a piece receives its finishing cut.

As stated above, it is desirable, generally, to present a sharp point of the diamond to the wheel in truing, but there are times when the smooth surface is preferable, particularly when it comes to producing a very fine finish; the flat surface of the diamond will tend somewhat to glaze the wheel and thus produce a better finish. Great care should be taken in handling wheels which are to be run at a high speed. They should be sound before mounting, and in order to determine this, hold the wheel and tap lightly with a hammer. If it does not give a clear ring, it is cracked and unsafe to use. Do not force the wheel on the center—it should fit close but not tight.

GRINDING WHEELS

If the hole is too small, rub it with a piece of broken wheel or an old file, to make it larger.

Wheels on surface grinding machines, whether embodying cylinder cup or regular wheels can be trued with diamonds, star wheel dressers or abrasive appliances. In each instance the device should be located in a special holder so that it can be held securely. Diamond nibs often are set in cast iron blocks which can be held readily on magnetic chucks. The same is true of star wheel dressers. Other devices are located in special holders.

Wheels on internal grinding machines should be dressed with diamond tools held in a holder provided for the purpose. The common practice, in some localities, of dressing these wheels with a fragment of a broken wheel or with an abrasive stick held by hand should be discouraged. An abrasive brick, held in a suitable holder, however, will give good results under some conditions.

Wheels on saw gumming machines, small bench grinders, etc., can be dressed satisfactorily with Metcalf dressers.

Grinding wheel dressing, whether it be coarse wheels for rough grinding operations or wheels on precision grinding machines of various types, should be performed by an experienced man. In many plants where a large number of wheels are used for such operations as snagging castings, general grinding, etc., one man is detailed to look after this work. In the field of precision grinding, however, each operator generally dresses his own wheel, but in instances where any doubt arises as to the operator's ability, the work should be done under the supervision of the grinding foreman or the plant grinding engineer.

WIRE-WEB WHEELS

Wire webs can be used in silicate wheels only for the heat necessary to bake a vitrified wheel would melt the web, which is brass. Wire webs could, of course, be incorporated in elastic wheels, but this never is necessary as the elastic bond in itself provides a substantial safety factor. It cannot be denied that the wire-web grinding wheel was an exceedingly valuable invention, but in common with many improvements of other days, it is thought by some authorities to have outlived its usefulness, inasmuch as present-day grinding wheels are

made by more scientific methods than were in vogue in the early days of the industry. Today safety in grinding wheel operation is assured by mounting wheels between safety flanges or by operating them under adequate metal guards.

A few purchasing agents continue to specify wire-web wheels and any grinding wheel manufacturer can supply them. The author recalls the superintendent of a large manufacturing plant who some years ago insisted on using wire-web wheels of safety flange shape. As a further assurance of safe operating these wheels were used under guards. Such extreme precautions, however, are not necessary.

SECTION X

HONING PRACTICE

The term *hone* is applied somewhat loosely to abrasive materials, both natural and manufactured, used for smoothing metallic surfaces. In present-day shop practice, however, honing is generally understood to refer to the method of finishing cylindrical surfaces, either external or internal, by means of abrasive stones which are termed hones. The process of finishing the bores of automotive engine cylinders with abrasive stones sometimes is called grinding. Following is a list of the subjects treated in this section, arranged in alphabetical order:

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HONING PRACTICE

CRANKSHAFT HONING

The process of finishing crankshafts by honing to remove minute marks left by the grinding wheel is a comparatively new development that is productive of excellent results. The Schraner crankshaft honing machine embodies means for locating and rotating the shaft while the bearings are gripped with heads which carry six hones each. L. A. Becker supplied the following data on crankshaft honing:

With the shaft in place in the machine and the honing heads on their respective bearings, the clutch is engaged which starts the shaft revolving. The shaft is driven by a lug in the headstock spindle, this lug being engaged by means of the headstock handle. The front end of the shaft is carried by a quick-acting tailstock with a live center. As the shaft revolves the platen on which are mounted the head and tailstocks, is given a reciprocating motion of $\frac{1}{8}$ -inch. To allow for this, the honing stones are $\frac{1}{8}$ -inch shorter than the length of the bearing on which they rest. Thus, by moving the shaft laterally as it revolves, an ideal honing condition is present and the possibility of scratches and lines is eliminated. The amount of reciprocation can be controlled by adjustment so that the bearing cheeks can be honed.

Each honing head carries a jet of kerosene which flushes each bearing continuously during the operation. Unclamping the heads automatically shuts off the kerosene for unloading and loading, and reclamping starts the flow. The kerosene bath facilitates the honing by keeping the stones sharp and preventing their surface becoming glazed. The machine is provided with an automatic knockout which can be timed by $\frac{1}{2}$ minute intervals from $\frac{1}{2}$ to 30 minutes. The average time required by users is two minutes.

A novel feature of the machine is a device which clamps all throw heads in the position they are left by the shaft when the machine stops. The operator can then open the heads and by turning the hand wheel the entire head assembly, which is carried on a slide, is lifted away from the shaft. This permits easy removal and reloading. The heads are then lowered by means of the hand wheel and since the new shaft is placed

in the machine with the throws in the same position as the one previously honed, the throw heads can thus be closed upon their bearings as quickly as the main bearing heads. An experienced operator will unload and load in about 20 seconds. Thus 2½ minutes floor to floor is a conservative average.

The surface left by the grinding wheel, under a high powered glass, is shown to be an area of hills and valleys, the hills being ridges, and very sharp. A cross section presents itself as decidedly saw-toothed. However, should a carefully ground crankshaft, taken directly from the finish grind, be assembled in a motor with sufficient bearing clearance and be very carefully run in, as it would surely need to be, it would in time develop excellent bearing surfaces throughout. The grinding marks would have disappeared and the surface become very smooth. But when this condition was reached, the bearing clearance would have become excessive, due to wear both on the shaft and in the bearings in which it turned, in addition to the abnormal clearance required by the original surface. Any grinding errors, if present, would have further increased this clearance. This is an extreme example, but it serves to illustrate a condition that can only be reduced in proportion to the quality of the bearing surface present when the motor is assembled. To put it in other words, the better the bearing cylinder as to surface and form, the closer can be the initial clearance and the more gradual will this clearance increase.

The honed crankshaft presents bearing surfaces equally as good, or superior to those of a hand-polished shaft that has been carefully run in for a thousand miles or more. By honing, the initial wear has been taken from the bearings before the shaft is placed in the motor. This removal of the initial wear and the correcting of grinding errors is the very essence of honing.

The process of honing evens the ground surface by leveling off the ridges left by the wheel, and if carried far enough, will result in a very smooth, hard and brilliant surface at a level slightly below the bottom of the grinding marks. Lapping, as distinguished from honing, will likewise remove grinding marks, but being a different process, the final results are not what is to be desired.

It is well to compare the two processes of honing and lapping. Lapping is a method of finishing whereby a piece, usually of metal softer than the work to be lapped and machined to approximately the contour of the work, is used in connection with a fine abrasive grain or flour. This abrasive is usually in paste form and applied to the lapping block, or lap as it is called, with a swab. The lap is held against the work and the latter revolved and reciprocated. The lap becomes charged with a part of the abrasive, but during the operation, those particles of abrasive that have not charged the lap are free to roll between it and the work. This causes pit marks, which, though very minute, give the surface a dull and milky appearance. Likewise these free particles, rolling as they do, form a cushion between the lap and the work and tend to wear down the low areas as well as the high, though to a lesser degree. This reduces the correcting tendency of the lap itself. The work leaves the operation more or less covered with the abrasive paste and great care must be taken that it is washed off thoroughly, lest some remain to play havoc later on.

Honing may be termed a modern method of lapping, using, as it does, bonded abrasive blocks or stones instead of a metal block charged with abrasive. The stones are arranged in holders and are dressed to the contour by means of a diamond. The hone, which is an assembly of one or more stones in the holder, is held against the work as the latter revolves and reciprocates. During the operation, the work and the hone are flushed continually, usually with kerosene. This both facilitates the honing by keeping the stones sharp and the work clean and does much toward preventing the stones becoming glazed. Honing is a much faster operation than lapping, as it removes more material in a given time. It also corrects to a greater degree and the quality of finish is far superior to that left by lapping. Eight elements, according to Mr. Becker, enter into the problem of honing a crankshaft:

1—Grade of stone. The bond must be of such type and hardness that it will allow the cutting grains to break away on becoming dull.

2—Grain of stone. Generally speaking, the finer the grain the higher the finish on the honed surfaces. More stock can

be removed with a coarse grain, however, and with very little sacrifice of finish.

3—Pressure. The pressure of the stone upon the work must be sufficient to keep the stone cutting until the bottom of the grinding marks is reached. Too little pressure will result in the glazing of stones, just as too light a cut will dull a turning tool. Too great pressure wears the stone away faster than the cutting particles lose their sharpness and makes the stones appear too soft. Since the shaft must reciprocate as it revolves, the stones must be shorter than the bearings on which they are working. If the reciprocation is $\frac{1}{8}$ -inch, which is quite generally the case, the stones are that amount shorter than the bearings. Thus, the stone length varies with the bearing length and the pressure applied must vary in proportion to the length of bearing in order to obtain approximately the same amount of pressure per unit of areas throughout. Provision is made on the Schraner machine for quick and easy adjustment of this pressure.

4—Speed of work. In honing as in grinding, the work speed has a very decided influence upon the finish of the surface, and upon the proper action of the stone. A stone that does not work well upon a given shaft at one speed, will give excellent results at another.

5—Time. Since honing is a finishing rather than a stock removing operation, it need not be carried beyond the point where a proper and satisfactory finish is reached. With a fine stone it cannot be carried farther, as the stone ceases to cut and becomes glazed. The action of the hone is very fast at first, slowing up as the surface improves, because, as the work progresses, the nearer the bottom of the grinding marks is reached and the more surface is presented to the stones. Probably 70 per cent of the desired result is accomplished in the first 30 seconds and 90 per cent in the first minute. Quite naturally, the quality of the finish grind will greatly affect these figures. The Schraner machine is provided with an automatic knockout which can be set for any desired length of time. This allows one operator to run several machines.

6—Dressing of stones. This is of importance with new stones particularly, as it shapes them to the contour of the

bearing and gives them an initial sharpening. If grade and grain of stones are right, pressure properly adjusted, speed of work correct and timing properly set, there is seldom cause to dress the stones but once as far as their action upon the work is concerned. Each shaft, as it is put into the machine, with its sharp ridges, resharpenes the stones. Thus, there is a cycle whereby the ground surface prepares the stone and the stone removes the ground surface, becoming somewhat dull in so doing, only to be resharpened by the next ground surface to be removed. However, if a grinding error is consistent on one or more bearings, it will gradually affect the stones working thereon and their correcting action be reduced. For that reason it is well to redress the stones at least once a day. This trues them and directs attention to any grinding error that may have developed as the redressed stones will immediately reveal it upon inspecting the first shaft. A stone dressing machine is provided for this purpose, using a diamond, and extra stone holders allow keeping one set of hones always dressed and in readiness so that little or no time is lost by the operator.

7—Flushing of work. The work must be flushed continuously during the operation. This aids in keeping the stones sharp and in preventing their glazing. Kerosene is an excellent wash, though a mixture of kerosene and lard oil in the correct proportion is even better. A sump is provided in the machine and the wash directed to each bearing. It automatically shuts off while unloading and loading. Being thoroughly strained and cascaded, it reaches the bearings perfectly clean. Due to this wash, the shaft is very clean as it leaves the machine.

8—Reciprocation. The work should reciprocate as it revolves to increase the shearing action of the stones and to preclude any possibility of their becoming grooved or of lines developing on the surface of the work. This reciprocation is so adjusted that the stones make contact with the cheeks of the bearings at each end of the stroke. The amount of reciprocation can be readily adjusted.

As stated before, the purpose of honing is to remove the initial wear that is left in an inferior surface and to give a perfect form to the bearing. By properly controlling the above elements of honing, this can be accomplished with the utmost

uniformity of results in all shafts, and since all bearings, both main and throw, are honed at once, the operation is done at a great saving of time over the old method. Thus we have the old story of a machine doing work better and faster than can be done by hand.

CYLINDER HONING PRACTICE

The *American Machinist* gives the following facts regarding cylinder honing at the plant of the Chandler Motor Car Co.:

The hones are carbide of silicon, 60 grit, and are set in holders with flat springs back of them. They are driven through a flexible joint rotated at 11 revolutions per minute. They work back and forth through the bore at 122 strokes per minute. It has been found best to have the hones extend an equal distance through the bore at each end of the stroke.

The hones are flooded with a mixture of kerosene and paraffine oil, in the ratio of 15 to 1. The paraffine is added solely because it is easier on the hands of the operator. A powerful magnet is placed at the end of the return pipe to the oil tank to catch the steel particles cut away by the hones. Hones are sometimes glazed very quickly but the glaze is readily removed by carefully rubbing a piece of abrasive wheel or block on the surface. Removing the glaze makes it possible to hone from 200 to 250 holes before truing the hones with the diamond. When truing becomes necessary, the hone blocks are locked in position on the heads and soaked in kerosene for several hours. They are then put in a lathe and trued with a diamond. After soaking in kerosene they cut very readily and wear the diamond very little.

As evidence that there are high spots left by the grinding wheel that are removed by the hones, the effect on the size of the bore is cited by honing advocates. The hones will remove 0.001-inch from the bore of an average cylinder in about 1 minute. But the next minute or two they will remove very little. The mathematical shark might say the increase in the amount removed is inversely as the square of the time. In other words, doubling the time after the first minute, results in very little metal being removed. The practice is to run the hones two minutes by a stop watch and the results are said to be remarkably uniform.

The allowance for grinding is from 0.006 to 0.007-inch. If the cylinders are reamed, it is customary to allow from 0.012 to 0.015-inch for the reamer to bite into, rather than attempt to scrape out half this amount.

At the plant of the Oakland Motor Car Co. cylinder blocks are bored, reamed and honed. About 0.015-inch is left for reaming and 0.00015-inch for honing. The block is located under a 6-spindle machine improvised from a multiple drill. The hones are driven by flexible joints so that they follow the reamed holes which are 2 13/16 inches in diameter and 9 inches long. Each hone head carries five carbide-of-silicon stones, 6 inches long and 3/4-inch square, 180 grit. The hones are rotated at 140 revolutions per minute and in passing down the bore they rotate nine times. They are lubricated with coal oil. Eighteen blocks or 108 bores are finished per hour.

At the plant of the Chrysler Motor Corp. cylinder bores are bored and reamed to within 0.004-inch of finish size and finished in two honing operations. A special machine adapted from a multiple drill is used. The hones are carbide of silicon, 60 grit for roughing, and 180 for finishing. The hone heads rotate 250 revolutions per minute and reciprocate 40 times a minute. Coal oil is used to keep them cool.

Exceptionally hard cylinder castings are incorporated in Lincoln motors, and it is felt that grinding is the most satisfactory way of obtaining the desired accuracy of finished dimension. Following this theory, cylinder bores are ground most carefully to the limits called for by the drawings. Then the cylinders are honed with practically no removal of metal. The purpose of the honing may be likened to the polishing operation in optical work where a condition of molecular flow rather than the removal of any material pertains. The grinding marks are "flowed" into the direction of the piston travel and in the process the bore is given practically a dead-smooth, homogeneous finish. Stones in the finishing tool are made as wide as possible. Rotation of this tool can be considered only as indexing to insure complete treatment of the wall surfaced as the major portion of the stones' effect is produced by the vertical reciprocation.

At the Dodge plant, cylinder barrels pass through two boring operations followed by semifinish and finish reaming

operations which leave about 0.0015-inch for the final operation. Particular attention is devoted to each of the preliminary operations in order to insure bores which are round and free from taper within close limits. As in the case of Lincoln bores in the final finishing operation, the head carrying wide abrasive stones is rotated only slightly and the finishing effect is produced almost entirely by their vertical reciprocation. However in this case, an abrasive action which removes about 0.0015-inch occurs and it leaves the final finishing marks in a vertical direction. The abrasive heads are indexed 15 degrees on the down stroke of the tool in the cylinder barrel and the upward travel is in a straight line.

In both the foregoing instances, the abrasive head "floats" and is centered by the bore. Therefore the condition of the bore at the beginning of the final operation has much to do with the possible benefits of this type of finishing. In fact, production engineers agree that with the proper abrasive head equipment, the factor which contributes most to the economy and excellence of the operation is condition of the finish reamed bore, particularly as refers to uniform size and freedom from taper.

On the operation of honing automotive engine cylinders, according to W. C. Hutto, experience has demonstrated that the stones should overrun the ends of the bore $\frac{3}{4}$ to 1 inch and they should completely overrun the middle point of the bore. That is the outer end of each stone should cross the horizontal center of the bore on each stroke. This point is highly essential to the production of straight bores of uniform size and can be attained by varying either the length of stroke of the reciprocating table or the length of the grinder stones. However, in practically all cases involving passenger-car engines of ordinary size, stones of 4-inch length will meet the situation.

One of the drawbacks to the utmost success of honing operations is the lack of power in existing equipment. For the cylinder of ordinary size, say 3 to $3\frac{1}{2}$ inches diameter, the best results are obtained through operating the honing heads at 350 revolutions and 75 reciprocation strokes per minute. With these speed characteristics, a superior finish will be obtained and the abrasive stones will wear satisfactorily with an almost complete elimination of glazing.

With abrasive stones of the correct grit and grade for iron of a given hardness, glazing can be charged to a slow operating speed. This is a condition much like that of chip clearance. When the speed is too low the abraded material piles up on the stones instead of being cut free. Another good result of the foregoing speeds of rotation and reciprocation is a finish mark pattern developed in which the interesting lines cross at almost right angles in a diamond-shape arrangement. The diagonals of these diamonds are in the vertical and horizontal planes and the vertical angles are slightly smaller than the horizontal.

The hone marks should be discernable but not prominent to insure the best commercial, or satin finish. Recently at the plant of a well known automobile manufacturing company a lot of 20 cylinders put through with a mirror finish which can be produced with practically the same ease as the commercial recommendation. In about two weeks time, the production department called back the blocks in question and canceled any further mirror finish as it was almost impossible to get rings to wear into a seal in these bores. The commercial or satin finish has been found to be one of the happy compromise which are so frequent in automotive production. At the end of the running in period, the cylinder shows no wear but a perfection of finish and simultaneously, the rings have come to a satisfactory seat.

It should be emphasized that in all honing operations kerosene should be used as a lubricant or coolant and it should be supplied in liberal volume. The selection of abrasive stones is governed by the hardness of the cylinder iron, the amount of stock to be removed, the character of finish desired and the speed of the operation as regards reciprocation and rotation. As a general rule, the hardness of the stones is inversely proportional to the hardness of the cylinder block casting.

The usual finish allowance ranges from 0.001 to 0.0015 inch for one grinding operation which is being performed in many plants in less than one minute floor to floor time. At the plant of the Hupp Motor Car Corp. a semifinishing grinding operation with rather coarse stones is followed. It is started with a finish allowance of 0.003 inch, allowing a maximum of 0.005 inch for the final satin finishing operation.

HONING LARGE CYLINDER BORES

Satisfactory results have been obtained by the Hutto Engineering Co. in finishing large bores by the honing process. In finishing a bore 64 inches long and $17\frac{1}{2}$ inches in diameter the limit of accuracy was 0.001-inch. The apparatus employed is of the double end of tandem type, there being a set of six stones at each end of the central driving member of the grinder, the overall length of which is less than half the length of the bore. This provides for an overlapping of the stone travel.

Before removing the stones from the bore, near the drive-end of which the grinder is always stopped, the adjusting screw is backed off, eliminating wall pressure on the stones. Thus they are withdrawn without leaving scratches on the bore surface. Occasionally it is necessary to dress the stones with the edge of a file or with a dressing stick in order to remove glaze or metallic particles. With an adequate flow of kerosene, careful adjustment of stones to keep them in close contact with cylinder bore wall while working, and as rapid reciprocation of grinding as may be consistent with the work being done, little trouble from glazing will be experienced.

SPECIAL HONING OPERATIONS

The Titan Machine & Mfg. Co. has made considerable progress in adapting the honing process to difficult work and also in finishing large bores by honing. Small hones are used by this company for finishing bronze bushings in pistons. The hone is said to give a much better finish than can be imparted with broaches or reamers. Square hones have been adapted for finishing holes in hardened transmission gears. Special hones have been developed for finishing small holes in such parts as sewing machine connecting rods. These holes are less than $\frac{1}{2}$ -inch in diameter.

An oil pressure cylinder for a conveying machine was honed satisfactorily. This was a blind-end cylinder, 5 inches in diameter and 18 inches long. The material was cast iron. It was finished with a hone carrying four stones. The hole was bored to within 0.010-inch of the desired size and then reamed to within 0.002-inch of the finish size. Liners for Diesel engine cylinders also were honed readily. These parts were cast iron 6 inches in diameter and $13\frac{1}{2}$ inches long. About 0.006-inch

was removed by honing. The hones were six in number, 8 inches long, 1 inch wide and $\frac{1}{2}$ inch deep. These bores were finished in five minutes each. The hones were lubricated with kerosene. The Titan company also has achieved success in honing blind-end cylinders for fire apparatus. These cylinders are $5\frac{7}{8}$ inches in diameter and 15 inches long.

TYPES OF HONES

Perhaps the most common form of hone is the type used for putting a fine edge on razors. In the strictest sense of the word, however, this abrasive medium is a sharpening stone and not a hone. Razor hones are made of various substances. The Belgian hone owes its cutting qualities to minute crystals of garnet. Razor hones also are made of carbide of silicon and aluminum oxide. The abrasive material used is in fine powder form, carefully washed and graded. These hones are made by the vitrified process.

The hones used for finishing automobile cylinders are a form of sharpening stone, carefully made from selected material and graded as to hardness very accurately. They are carbide of silicon in various fine grits, No. 180 being popular. In operation these hones are lubricated with coal oil.

The term honing also is applied to the finishing of marble and other stone surfaces. The hones in this case are specially shaped blocks fitted into a revolving head, or holder. The hones used are carbide of silicon or artificial aluminum, generally in FF grit and shellac bond.

The so-called *hone gangs* are used in large quantities for smoothing down *rough stuff* in automobile body finishing. These hones are a variety of sandstone quarried principally at Floyds Knob, Ind., by the American Rubbing Stone Co. A hone gang is made up of a number of small blocks of this sandstone arranged in the form of a rectangle and bound together with a strip of cloth wound around the outside. Thus when the device is held in the operator's hand, it gives to conform to a slightly curved surface. Rotary hones, or oilstones, are used for putting fine edges on woodworking tools, scrapers, etc. These are very fine abrasive wheels or natural stones such as the Washita and Arkansas varieties. Rotary hones generally are operated at peripheral speeds ranging from 500 to 600 feet per minute. They are lubricated with coal oil.

SECTION XI

MISCELLANEOUS ABRASIVE DATA

This section is devoted to data pertaining to various abrasive-engineering subjects which are arranged in alphabetical order as follows:

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Abrasive Specialties	386	Metallic Abrasive Manufacture	411
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MISCELLANEOUS ABRASIVE DATA

ABRASIVE ACTION

The literal definition of abrasive action is to abrade or wear away; and while this definition may apply to some of the older abrasives, it does not apply equally well to the modern abrasives which remove metal by a cutting action. This is proven by examining the chips ground away by a modern wheel under a powerful microscope. It will be found that they resemble chips made by a metal turning or planing tool very closely. Abrasive action, today, is more of a cutting than an abrading operation. A modern grinding wheel does not abrade the work—it cuts it. However, as no word in the English language exists that defines the action of a grinding wheel correctly, the terms abrasive and abrasion will probably be used for many years to come.

ABRASIVE BRAKE SHOES

These appliances consist of railroad equipment brake shoes fitted with inserted abrasive blocks, usually aluminum oxide. The object is to keep the wheels true by wearing them evenly. Such devices are said to show good results and to make it unnecessary in many instances to dismantle rolling stock for the purpose of truing the wheels. Several types of abrasive brake shoes made by the Wheel Truing Brake Shoe Co., are shown in Fig. 1.

The cross-hatched portions represent nonabrasive and the other shading abrasive compositions. The arrangement shown at *A* is used for grinding the inner part of the wheel tread next to the flange. The reverse of this arrangement is shown at *B*, this shoe being used for grinding the outside of the tread and the flange height. This type of shoe is used for truing tread-worn wheels. A popular type is shown at *C*. This is used for taking out flat spots. It does not act on the flange. A type of shoe for operating on the flange only is shown at *D*. The arrangement shown at *E* reduces the wheel diameter and removes flat spots. It operates on the flange and tread simultaneously. When it is necessary to treat the outside of the tread only, the type, *F*, is used. The reverse of this arrangement is shown at *G*. This design is used for cutting down the flange and the part of the tread next to it. For operating on the

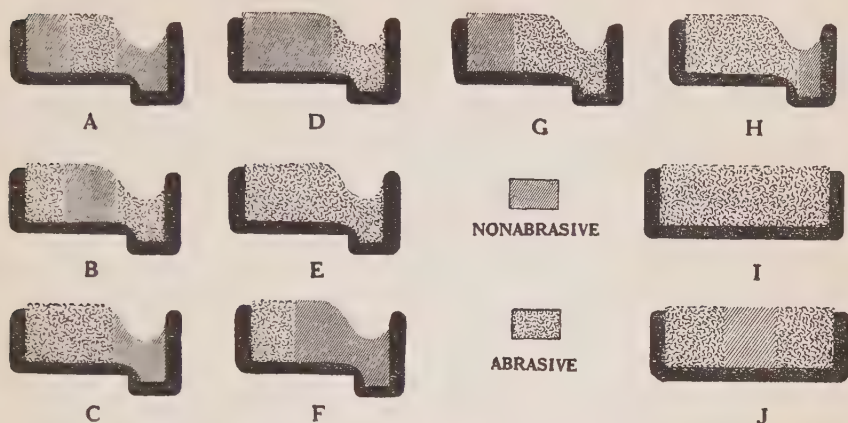


FIG. 1—VARIOUS FORMS OF ABRASIVE BRAKE SHOES

entire width of the tread and a part of the flange the shoe, *H*, is used. The arrangement shown at *I* is used for reducing the diameter of blind wheels or taking out flat spots. Blind wheels are made without flanges. They are used on some locomotives. The shoe shown at *J* is for repairing tread-worn blind wheels.

Abrasive brake shoes are not a cureall by any means and when wheels are badly worn it is recommended that they be turned or ground. However, when the treads of locomotive wheels have been worn to a depth of $5/32$ -inch (half the factor of safety limit) they can be trued readily by applying abrasive shoes. Those are used until the wheels have been ground true. Then they are taken off and the regular shoes substituted. When abrasive shoes are used properly, the wheels can be kept in service for their entire life without regrinding. The shoes are used in every kind of service and on all except freight cars. Because freight cars are transferred from one line to another, the use of these shoes is impractical. If installed by one road they might be forgotten by another and the shoes then would do more damage than the good for which they are devised.

ABRASIVE ENGINEERING

While no engineering college gives the degree of "Abrasive Engineer," such a profession is becoming to be recognized, due to the important part grinding and other abrasive processes are playing in present-day production methods. The fact re-

mains that there are a large number of men who, to all intents and purposes, are abrasive engineers. These men have made a life study of abrasive practices and their opinions are valued and favorably commented upon. Abrasive engineering can be called the practical application of abrasives to every-day production methods. The future for it is promising.

ABRASIVE SPECIALTIES

This term is applied loosely to a variety of abrasive products such as sharpening stones, razor hones, razor strops, hand grinders, engravers' points, knife sharpeners, valve grinding compounds, etc. Such articles are produced by a number of abrasive manufacturers with the object of making a complete line. This practice also enables the abrasive manufacturer to find a ready market for superfluous abrasive materials, particularly those in fine grains.

ABRASIVE TILE

This material consists generally of a ceramic or cement base with the upper surface impregnated with abrasive material in a predetermined amount. The amount to apply to a surface for a specific use has been adjusted to a nicety. Experiments have shown that too great an amount of abrasive material slows traffic in densely crowded places such as walkways leading to underground railways, etc. Both alumina and carbide of silicon can be used in making abrasive tile. Nosings for stairs, treads, etc., sometimes are made of a special mixture that contains a large amount of abrasive. Another method consists of facing molds with abrasive so that when the casting for a stair tread for example, is poured in the mold, the upper surface will grip the abrasive material firmly. Abrasive tile is used extensively on stair treads, elevator fronts, walkways, ramps or, in fact, in any place where the danger of slipping must be prevented.

ANTIFRICTION BEARINGS

Ball and roller bearings are employed to quite an extent in the spindles of grinding machines, both for precision and rough work. This practice has been extended to quite an extent during the past few years. Formerly it was thought that ball bearings were not ideal for this work on account of the single-

point contact. With certain types of equipment, at any rate, this has been proven to be a fallacy. Ball bearings are used in vertical spindle surface grinding machines, cylindrical grinders, disk grinders, side surfacers or ring wheel grinders, internal grinding spindles, floor stands, etc. Ball bearings must be kept free of dirt or they will wear out rapidly. The type of bearings used are not adjustable, like a bicycle bearing for example, so that wear cannot be taken up. However, as such bearings generally are contained in dust-proof housings they can be kept clean. In case of excessive wear they can be renewed at low cost. Taper roller bearings are used in the spindles of some grinding and polishing machines. They offer one advantage in that they can be adjusted to compensate for wear.

BALANCING APPLIANCES

The oldest form of balancing appliance is the so-called balancing ways, which are two metal surfaces set as nearly level as possible. The part to be balanced is placed on an arbor, which in turn is set on the ways. The heavy part of the object causes it to roll so that the heavy side rests downward. An improved form of balancing appliance is the so-called roller balancing stand. The balancing arbor is set on a pair of offset knife-edge rollers, which in turn rotate on ball bearings. These appliances are productive of accurate results as it is not necessary to level them accurately.

The foregoing applies to static balance. Dynamic or running balance is a more sure guide for accuracy. Dynamic balancing machines are of several types. One developed by the Norton Co. for balancing such parts of automobile crankshafts is equipped with two needles which vibrate when the rotating shaft is out of balance. When the shaft has been put in balance, the needles remain stationary.

CARE OF GRINDING MACHINES

The first essential in the care of a grinding machine is to see that it is oiled at frequent intervals. In many large plants, where grinding machines are used continuously, a man is detailed to look after this work. All oilers, channels, feed tubes, etc., must be free of grit and dirt, otherwise the lubricant will not be delivered to the working surfaces. Ordinary machine

oil will suffice for lubricating sliding surfaces, etc., but a high grade of special oil of light body should be used for a spindle lubrication.

On precision grinding machines, the spindle boxes should be kept adjusted closely so that they will warm up while in operation. However, the journals should not be permitted to become hot enough to prohibit bearing the hand on them. In adjusting spindle boxes to compensate for wear, it is best to follow the directions supplied by the grinding machine maker. In any event, the work should be entrusted to an expert only.

Grinding machines should be cleaned at frequent intervals, at least once a week. The practice of other days of allowing one-half an hour on Saturday for cleaning machinery certainly was productive of excellent results. In modern grinding rooms, however, where a number of men are employed, it is good policy to leave the cleaning to men detailed for this work.

An ordinary precision grinding machine, if it receives proper care, can be depended upon to operate for many years with minor repairs only. In time, however, natural wear will necessitate the fitting of new journal boxes and the rescraping of sliding surfaces. When it is necessary to refit the spindle boxes, the spindle journals should be reground and then lapped to remove the wheel marks. Sliding ways must be scraped to a master and then the two sliding surfaces scraped together. Economy is shown by employing the grinding machine manufacturer's service men on this work. Through long experience they are capable of performing the work in a minimum amount of time. Again, they are machine tool men in the strictest sense of the word, while the men on the ordinary repair gang, while they may be skilled mechanics, often lack the necessary knowledge to repair precision grinding machines correctly and efficiently.

Grinding machine centers should be reground at frequent intervals to make sure that they present a true 60-degree angle. Otherwise accurate work cannot be assured. Where a number of precision grinding machines of one type are used, it is a good plan to keep extra centers in the tool crib so that the grinding machine operators can exchange worn ones for ones that have been reground.

If a grinding machine is used intermittently, the cooling

solution should be wiped away from all finished surfaces and the machine rubbed with a piece of oily waste or a wiping cloth. If a machine is to be out of commission for any length of time it is a good plan to cover it with a tarpaulin to exclude dust.

GRINDING AND POLISHING EXHAUST PRACTICE

The following data were supplied by H. W. Pfeffer of the American Blower Co.

Air in motion in a duct system is influenced by velocity pressure; static pressure, sometimes called friction pressure; and total pressure, or total head; which is the sum of the velocity and static pressures. It is necessary therefore that these three pressures be defined clearly.

Velocity pressure creates the flow of air. Static pressure is measured at right angles to the direction of flow and is required to overcome the resistance offered by the piping, etc., to the flow of air. Total pressure is the sum of the two which creates the flow and overcomes the resistance to the flow of air. Pressures usually are expressed in terms of inches in a water gage. For example, an imaginary system may require a velocity pressure of 1-inch water gage, and the resistance to the flow of air, or static pressure, is 2 inches water gage, thus making the total pressure at the fan 3 inches water gage.

Expressing pressure in terms of ounces per square inch is still not uncommon but the practice is fast becoming obsolete, as the measurements usually are made with a water gage in inches and transferred to ounces per square inch. One-inch water gage pressure equals 0.577 ounce, or one ounce equals 1.73 inches. The pressure ratings of exhaust fans are made on a basis of either total pressure or static pressure at the fan. Some manufacturers use total pressure as the basis of rating the fan air delivery, while others use the static pressure as a basis. This fact should be borne in mind when making comparisons of fans manufactured by different companies.

One of the most important considerations in planning an exhaust system for removing refuse is the design of the hoods to which the piping is connected. The first consideration should be to close in as much as possible the source of dust. This makes it possible to handle it with a minimum volume of air

and at the same time insures the maximum degree of effectiveness. It is obvious that the hood or enclosure must be designed so that it will not interfere with the efficiency of the workman or process. As an efficient system requires the handling of a minimum volume of air at the lowest possible velocity, care also should be exercised to catch the materials to be conveyed in the same direction that they naturally take when leaving their source. They can then be picked up with a current of air moving at a much lower velocity than would be needed otherwise. Fig. 2 shows a typical layout for an exhaust system.

From actual practice, minimum duct velocities have been determined for handling various materials, and while it is not

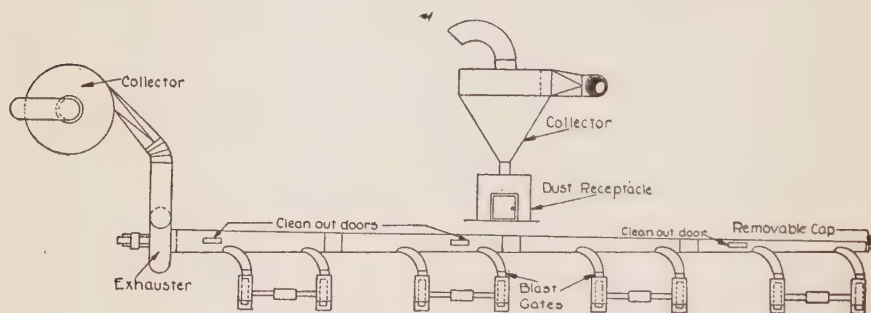


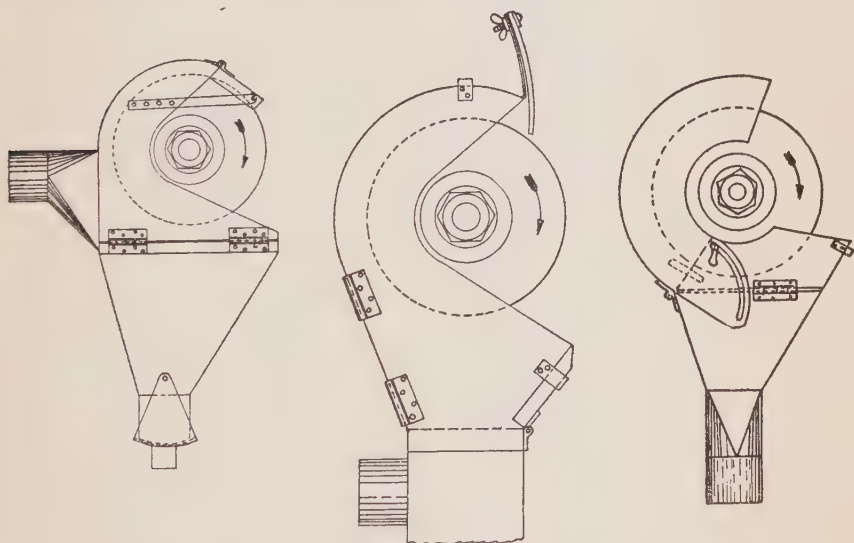
FIG. 2—TYPICAL LAYOUT FOR AN EXHAUST SYSTEM

possible to lay down any inflexible rules, below are given velocities usually ample for a given class of work.

Approximate duct velocity, air 70 degrees, Fahr., feet per minute	Velocity pressure at hood, inches in water gage	Class of material handled
2750	$\frac{1}{2}$	Gases, fumes, and very light materials
3500	$\frac{3}{4}$	Cotton, wool, and similar materials
4000	1	Dust from shoe machinery, sawdust, dust from light polishing and buffing wheels
4500	$1\frac{1}{4}$	Ordinary woodworking plant refuse, dust from heavy polishing and grinding
5650	2	Refuse from woodworking machinery taking heavy cuts at high speeds or cutting green or wet lumber
6350	$2\frac{1}{2}$	Heaviest materials generally handled, such as sand, grain, etc.

However, in some sections of the country it will be found that local and state ordinances specify the minimum velocity pressures. Figs. 3, 4 and 5 are various hood arrangements which have been found effective. Hood connections should

enter the main suction duct at an angle not exceeding 45 degrees and they must incline in the direction of the air flow. Ends of the piping must not project into the main pipe, and the pipe should be made so that all laps in piping point in the direction of air flow. All bends, turns or elbows in the hood connections or mains should have a radius in the throat of at least one and one-half times the diameter and preferably two times the diameter of the pipe. All connections should have a shut-off gate; bringing two hood connections into the main exactly opposite each other should be avoided. Wherever material is liable to accumulate in the main or branches, clean out con-



FIGS. 3-4-5—EFFECTIVE DUST COLLECTING WHEEL HOODS

nections should be provided. Hood connections and mains should be as short as possible and as free from bends as the work will permit so as to keep the friction low. The recommended sizes of hood connections are given below and from these the main pipe sizes can be determined by adding the area of each hood connection to obtain the area of the main.

Wheel size, inches	Grinding	Buffing and polishing
To 6 x 1	3	4
7 to 16 x 2	4	5
17 to 24 x 4	5	6

Having covered hood design, with its connections, and hav-

ing covered the velocities required from which we obtain the volume of air to be handled and proportioned the mains from the areas and volumes handled by the various branch hood connections, we have now to determine the friction loss of the system from which the static pressure is obtained. It has been found by experiment that elbows or bends with a radius of approximately one and one-half times their diameter have a friction loss equal to a straight pipe with a length of six times its diameter. For example: A 24-inch elbow with a radius one and one-half times its diameter is equivalent to adding 12 feet of 24-inch pipe.

On straight piping, it is found that a pipe 40 times as long as its diameter causes a resistance to the flow or friction pressure equal to the velocity pressure existing in the pipe. For example: If we have a 30-inch diameter pipe with air traveling through it at a velocity of 4000 feet per minute corresponding to a velocity pressure of 1-inch water gage, we will find that for every 100 feet of straight pipe (which is 40 times the diameter) the resistance will equal 1-inch.

The chart in Fig. 6 is plotted so that friction loss in inches of water may be obtained for any diameter of pipe with any velocity of air in feet per minute. This is based on 100 feet of straight pipe. For example: we will take the before mentioned pipe of 30 inches in diameter with 1-inch velocity pressure and 100 feet in length. We know from the foregoing that 1-inch velocity pressure equals 4000 feet per minute velocity and on referring to Fig. 6 we find the line running upward at an angle on the diameter of pipe side marked 30 inches. Follow this until we reach the line marked velocity 4000 feet per minute, carrying this horizontally across, we find that 20,000 cubic feet of air per minute is flowing through it, or follow the vertical line downward, and we find that the friction in inches water gage is 1 inch. If the pipe is only 10 feet long, the friction is only 1/10 inch. Following are data on 90-degree elbows with various radii in the throat. In determining the static pressure required, the friction of the piping on the discharge side of the fan should also be added to that on the suction side, as this is additional work which the fan performs.

MISCELLANEOUS ABRASIVE DATA

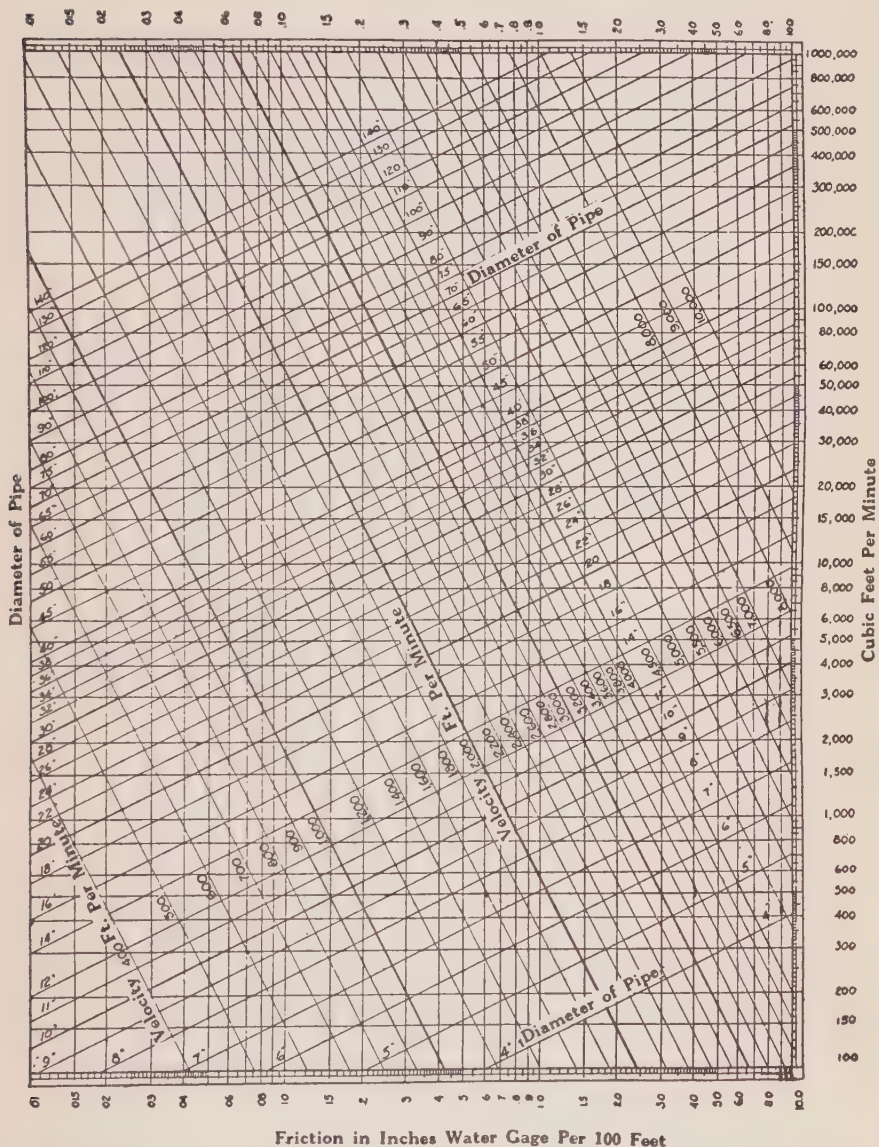


FIG. 6—CHART FOR DETERMINING FRICTION LOSSES IN EXHAUST SYSTEMS

Radius of throat of elbow in diameters of pipe
 $\frac{1}{4}$ $\frac{1}{2}$ $\frac{3}{4}$ 1 $1\frac{1}{4}$ $1\frac{1}{2}$ $1\frac{3}{4}$ 2 $2\frac{1}{2}$ 3 $3\frac{1}{4}$ 4 $4\frac{1}{2}$ 5 $5\frac{1}{2}$
 Number of diameters of straight pipe offering equivalent resistance.
 67.0 30.0 16.0 10.0 7.5 6.0 5.0 4.3 4.5 4.8 5.0 5.2 5.5 5.8 6.0

The foregoing shows the frictional resistance of elbows of various radii in the throat of the elbow expressed in diameters of the pipe or elbow, the

result being expressed in the number of diameters of straight pipe offering an equivalent resistance as found in Fig. 6.

An example will clearly illustrate the facility with which the friction can be determined: Assume it is desired to discharge 40,000 cubic feet of air per minute through a duct 50 inches in diameter and 75 feet long. Find 40,000 cubic feet on right hand margin of the chart; follow horizontal line across to the left until it intersects with diagonal line marked 50 inches; now follow down perpendicular line marked to bottom of chart, where will be found the friction in inches of water, which in this case amounts to 0.31 inches per hundred feet of pipe. As the friction is in direct proportion to the length, then for 75 feet the friction will be:

$$\frac{0.31'' \times 75'}{100'} = 0.2325''$$

Assuming again that there are two elbows in the above 50-inch pipe, one having a radius in the throat of the elbow equal to the diameter of the pipe, or 50-inch radius, while the other has a radius equal to two diameters, or 100 inches.

From the table above find below radius of one diameter, 10 diameters for length of equivalent straight pipe, and opposite radius of two diameters,

$$4.3 \text{ diameters. Hence: } \frac{50'' \times 10}{12} = 41.66' \text{ and } \frac{50 \times 4.3}{12''} = 17.91'. \text{ The sum of these amounts to 59.57 feet or say 60 feet of 50-inch pipe. Therefore, } 0.31 \times 60'$$

$\frac{100'}{100'} = 0.186$ inches friction. Adding this to friction of straight pipe as already determined makes the total friction amount to 0.4185 inches.

Table III can also be used for rectangular ducts by reducing the latter to round ducts having the same frictional surface in the walls of the pipe, thus:

$$d = \frac{4 a b}{2 (a + b)}$$

a = width of a rectangular pipe in inches.

b = depth of rectangular pipe in inches.

d = diameter of round pipe in inches, in which the air is flowing at the same velocity that will set up the same frictional resistance as the rectangular pipe.

The shape of a rectangular pipe has a decided effect on the friction, for example: a 12-inch x 12-inch pipe offers the same friction as a 12-inch round pipe, whereas a 24-inch x 6-inch pipe, though having the same area as the 12-inch x 12-inch pipe, presents as much friction as a round pipe only 9.2 inches diameter. In other words, while the carrying capacity of the 24-inch x 6-inch pipe, as compared with a 9.2-inch round pipe, is more than double at a given velocity—yet the frictional resistance to the flow of air is the same in either case.

Following are a few conventional rules which are often of value:

Inches water gage may be converted into ounces per square inch by multiplying by 0.58 or by dividing by 1,728.

Friction for varying diameters of round pipes is inversely proportional to the diameter at a given velocity.

For rectangular pipes, the friction varies inversely as the square root of the area.

Friction varies directly as the square of the volume at a constant temperature.

Friction varies directly as the density of the air.

The density of air varies inversely as the absolute temperature.

Absolute zero is assumed to be—460 degrees Fahr.

MISCELLANEOUS ABRASIVE DATA

There are many designs of collectors on the market. It should be borne in mind always that the collector should be proportioned to the size of the entering pipe. For convenience in estimating the resistance of collectors, it will be found that the pressure loss in a collector will rarely exceed the pressure corresponding to the velocity in the pipe entering the collector. It is frequently less, depending on the design. Below are given suggested gages of metal pipes for exhaust work:

Diameter, inches	Gage of metal
Up to 5	26
6 to 8	24
9 to 15	22
16 to 24	20
25 to 32	18
Over 32	16

Note—Joints must be soldered air tight.

The static pressure against which the fan operates is obtained by adding to the friction loss in the ducts the initial pressure loss where air enters the pipe connections from the hood plus the pressure loss due to the collector. A close estimate of the initial or entrance pressure loss may be obtained by taking 50 per cent of the velocity pressure at hood. The capacity of the fan in cubic feet per minute is obtained by multiplying the velocity of air in the main duct (in feet per minute) by the area of the duct in square feet. Fans for use in exhaust systems for polishing and grinding rooms must be of rugged construction, low power requirement and relatively low speeds.

Grinding and buffing wheel systems should be kept separate because sparks from the grinding wheels may set fire to the lint and dust from the buffing wheels if both are carried through the same suction main. In large exhaust systems, it is often advisable to divide the machines to be cared for into convenient sections and take care of each section separately with a fan and collector. The material from the several collectors can discharge into the inlet of a separate exhauster which will carry the material over to the final collector, using less air and horsepower. Where any long distance blows are encountered, it is good practice to split the distance in two and put in a booster fan, connecting the discharge of the first fan into the inlet of the booster. This will save power and keep the fan speeds down where such conditions are encountered.

STATE-LAW REQUIREMENTS FOR DUST DISPOSAL

The first point to consider in dust disposal is the state law, if any, which specifies the amount of suction necessary. No hard and fast rules have been established to determine what constitutes an effective dust exhaust system. In some states the law requirements are rigid, in other localities they are lenient. Ten states make special mention of the disposal of grinding wheel dust. With the exception of the states of Illinois, New Jersey, Michigan, Ohio and Wisconsin, the laws require only that dust is to be removed as far as practicable. Twenty-eight states and the District of Columbia have no special laws regarding dust disposal. According to the Wisconsin code, the suction in the hood connection must be sufficient to raise a column of water in a U-shaped tube five inches and the test must be made as follows:

"A hole $\frac{1}{8}$ -inch in diameter must be made in the suction pipe approximately 12 inches from the connection to the hood. A rubber hose attached to the U-tube must be placed over the hole and the test made under these conditions. When the water in the U-tube stands at 0, the five-inch displacement is secured when the column of water rises $2\frac{1}{2}$ inches above 0 and the other column of water falls $2\frac{1}{2}$ inches below 0."

According to the New Jersey code, sufficient suction must be maintained in each branch pipe to displace two inches of water in a U-tube. The New York code states that sufficient static suction shall be maintained in each branch pipe within one foot of the hood to produce a difference in level of at least two inches of water between the two sides of a U-tube.

According to the United States Public Health service, a standard which depends solely on a suction head in the exhaust pipe is inadequate as a measure of the actual protection afforded the worker. The difference between the New York and the New Jersey standards of two inches and the Wisconsin standard of five inches indicate that the evidence on which even this imperfect standard has been based must be inconclusive. A more valuable standard from a sanitary viewpoint would be one based on the actual velocity of exhaust at the actual point of dust production instead of in the suction head in the duct below. The only standard that can be entirely satisfactory is one that deals directly with the actual condition of the air

inhaled by the worker. What we must rely on in the future is a standard that is based on the number and weight of dust particles actually contained in the air breathed by the worker.

GRADING OF ABRASIVE MATERIAL

After abrasive materials have been crushed it is necessary to grade them into specific sizes. This is accomplished by feeding the crushed abrasive onto a series of tilted reciprocating screens, arranged end for end. The coarser screens are brass wire mesh, the finer, silk bolting cloth. As the abrasive passes over the screens it falls through openings into bins. Thus it is graded into standard sizes such as No. 6, 8, 10, 12, 14, 16, 20, 24, 30, 36, 46, 54, 60, 70, 80, 90, 100, 120, 150, 180, 220. A number 20 grain, for example, is one that will pass through a screen having 20 openings to the linear inch. Such a grain would be retained on a screen having 24 openings. As the screens wear through abrasive action they must be replaced frequently.

It can be readily seen that the size of the wire of which the screens are composed and the skill exercised in weaving the screens influences the size of the grain. Many years ago considerable confusion resulted from the fact that a No. 24 grain, for example, made by one company did not match the No. 24 produced by another manufacturer. During March, 1922, however, the Grinding Wheel Manufacturers' Association of the United States and Canada adopted definite standards for grading screens and since that time the difficulty encountered by a number of standards has been eliminated.

Grains finer than 220 are designated as powders. They are known as F, FF, FFF, etc. They are graded in water. Finer powders, known as minute powders, also are graded in water. Thus a 10-minute powder is one that required 10 minutes to settle in water. The finest abrasive powder is known as 60-minute.

Abrasive paper and cloth generally is marked in grit numbers such as $\frac{1}{2}$, 1, 2, etc. Some confusion results as the numbers used to designate various materials do not agree. For example, there is quite a difference between 2/0 flint and garnet paper. The following data, furnished by the Carborundum Co., is useful in comparing abrasive paper and cloth grit numbers:

THE ABRASIVE HANDBOOK

Carborundum	Flint	Garnet	Emery	Manufactured alumina
FF	.....	.....	.....	.....
F	.....	.....	.....	.....
220	.....	.....	.....	.....
180	3/0	4/0	3/0	3/0
150	.....	3/0	2/0	2/0
120	2/0	.....	0	0
100	0	2/0	100	100
90	1/2	0	1/2	1/2
80	.....	.....	1	1
70	.....	.....	1 1/2	1 1/2
60	1	1/2	2	2
50	1 1/2	1	.....	.....
40	2	1 1/2	2 1/2	2 1/2
36	2 1/2	2	.....	.....
30	.....	2 1/2	3	3
24	3	3	3 1/2	3 1/2
20	3 1/2	3 1/2	.....	.....

GRINDER'S CONSUMPTION

Grinder's consumption is a common term applied to a form of tuberculosis technically termed *silicosis* or *fibroid phthisis*. It is caused by inhaling silica dust. A physician who had an excellent opportunity to study this disease in a New England town submitted the following interesting communication to the United States Public Health Service:

"I have seen a number of cases of the so-called grinder's consumption. The symptoms are excessive shortness of breath on slight exertion, dry cough and great prostration. At the present time the grinders are Poles and Finns. The disease attacks them more frequently and it is more fatal than among the grinders of former years and of other nationalities. Forty years ago I found victims among Yankees who were axe grinders some 20 years previously. These men could grind from 18 to 20 years before giving up the work. French Canadians next took their places. They generally lasted from 12 to 16 years. Swedes followed next, taking the disease in eight to ten years. Finns and Poles are now engaged in the work, taking the disease in three to five years."

Grinder's consumption is caused primarily by particles of dust irritating the operator's throat and lungs. Thus, if means are taken to reduce the amount of dust created by the grinding operation, the hazard can be reduced to a minimum, if not eliminated entirely. The grindstones used in axe factories are approximately seven feet in diameter and one foot wide and

as they are completely worn out in three weeks it is evident that a large amount of dust is created.

Of course, the greater part of the dust is carried away in the form of sludge, but enough floats in the air to cause trouble. One remedy is to run a liberal stream of water on the stone at all times. Another remedy consists of the operator wearing a respirator which filters the air as he breathes it. Grinders object to wearing these devices, however, claiming that they are hot and inconvenient.

As to the most common causes of grinder's consumption, authorities differ. F. H. Rauh of J. Wiss & Sons Co., cutlery manufacturers, furnished the following interesting data:

"Whether dust arising from abrasive wheels has a tendency to develop grinder's consumption is a question which doctors disagree. From my own experience I can state that I never seen a case of consumption which could be ascribed to emery dust. In fact, I cannot recall a case of consumption in the past 12 or 15 years and during that time I have been handling from 3000 to 4000 men.

"I do recall that in my younger days spent in the Middle West factories a number of the wet grinders (men working on natural sandstones running in water) died of tuberculosis. This was laid to the fact that these men almost invariably were heavy drinkers and it also is quite possible that the sanitary arrangements were not as efficient as those of the present time. Today the natural sandstone is almost entirely in disuse in cutlery manufacturing shops, they having been replaced by manufactured grinding wheels. These wheels on account of their greater ease of truing are comparatively clean to work upon."

Fayette R. Plumb Inc., manufacturers of hammers and hatchets, sledges and axes, furnishes some interesting facts regarding the dust hazard. At the plant of this concern grinding wheels have been substituted for grindstones. William D. Plumb, factory manager, submitted the following:

"We are certain that the use of dry grinding wheels decreases the hazard of grinder's consumption. The wet grinders used to get wet and thus they caught cold. They did not take care of themselves and continued to catch colds, developing at first what might be called a chronic cold. The membranes of

the throat and lungs became raw and breathing in the grind-stone dust was very likely to cause grinder's consumption.

"Since we have done away with the wet grinding room, the men are not as subject to colds as formerly and, consequently, they are less liable to be affected by dust. The blower system in our grinding rooms reduces the dust hazard to a minimum. In selecting grinders we exercise care to see that the applicants are men with strong lungs. With this simple precaution, no cases of tuberculosis have developed. Of the men who have remained with us for several years, we have noticed no falling off in weight or other signs of failing health. By selecting the proper men and by installing an efficient dust exhaust system, using the dry grinding method, the old bugbear of grinder's consumption, in our opinion, can be eliminated entirely."

In precision grinding operations where the work is cooled with a liberal stream of soda water or other solution, the dust hazard is reduced, as the particles of dust are washed away as soon as they are generated. The Packard Motor Car Co., furnishes some interesting data regarding grinders' consumption. The company operates a large number of precision grinding machines. F. X. Wells, safety engineer of the Packard plant, stated as follows:

"We have gone over our hospital records for the past five years and we do not find a single case of grinder's consumption due to a wet grinding operation."

The fact that workers in abrasive and grinding wheel manufacturing plants are constantly exposed to fine abrasive dust is well known. As a matter of fact, however, these operators are not attacked by grinder's consumption. A. C. Pemberton, managing director of W. J. Davies & Sons Ltd., British abrasive manufacturers, states that a number of employes at the Davies works have completed a half century of service, showing no ill effects from the inhalation of abrasive dust. He is of the opinion that emery dust acts on the lungs as does coal dust in *preventing* tuberculosis.

GRINDING GAGES

Grinding gages are appliances for noting the decrease in diameter of cylindrical work in process of grinding. They are of two kinds. The Pratt gage has a yoke that surrounds the

work. This yoke carries two fixed and one movable diamond pointed contracts. The upper one is connected to a lever that actuates the hand of a dial gage. The entire device is mounted so that it can be swung up out of the way when changing the work. The Arnold gage works on a different principle. It is equipped with hardened and ground shoes that fit the work so that a set of shoes is necessary for each size ground. The coming together of the shoes as the work is reduced in diameter actuates an indicator needle so that the operator can observe when the predetermined size is reached. This device can be removed entirely when it is necessary to change the work.

GRINDING WHEEL SUPERVISORS

Grinding wheel supervisors are men employed in a few of the large automobile and motor manufacturing plants to look after grinding wheels. Such men order wheels for stock as well as for trial purposes, look after all tests of abrasives, etc. Probably not over 50 such positions exist in the United States at the present time, but as a capable wheel supervisor can save a large company a substantial sum annually, the time is not far distant when such positions will be more common than they are at present.

IRONING WHEEL

A device used for finishing flat surfaces on stone with abrasives. Ironing wheels are of various patterns and a number of such appliances have been patented. A popular form, much used in the Quincy, Mass., district consists of a disk from two to three feet in diameter and in inch or more in thickness carrying a number of slots. This device looks like a circular boiler grate. It is located by means of a flexible coupling in the end of a vertical shaft so arranged that it can be moved over the stone surface in all directions. Various abrasives are used in the finishing process, called *ironing*, carbide of silicon, sand, metallic abrasives, etc.

LUBRICATION OF GRINDING MACHINES

The following data of grinding machine lubrication were furnished by A. F. Brewer of the Texas Co.: Ball bearings, and in certain cases roller bearings, have been found to be adaptable by certain machine builders as a means of insuring

effective operation of such elements as the idler and main drive shaft especially. The main spindle is regarded as the most important member from the viewpoint of lubrication. The important point in oiling grinding machines is the original selection of the lubricant to be used, and the consideration of its characteristics as required by the principles of antifriction bearing construction and operation. In such bearings the purpose of lubrication is to facilitate as easy rolling as possible. To enable this, however, all the surfaces must be in as perfect condition as practicable.

As a general rule, as light a lubricant should be used as can be successfully retained in such a bearing commensurate, of course, with the temperatures and pressures involved. Where practicable an oil with a viscosity of from 100 to 200 seconds Saybolt at 100 degrees Fahr. will be best.

Where there is possibility of oil leakage, however, or under conditions of dust, dirt or dampness it may be advisable to resort to grease as the lubricant. Greases furnish better seals against the entry of dust, dirt and moisture, thereby serving to protect the highly finished surfaces of the bearing elements in a very satisfactory manner.

Grease also can be very much more effectively retained in a non-oil-tight housing; on the other hand, dirt or grit that finds its way into a grease lubricating bearing, has no means of settling out, but is always held in suspension, being carried back into the bearing repeatedly.

Where the grinding machine wheel spindle is built with plain or so-called sleeve-type bearings the sight feed oil cup has been proven to afford the requisite degree of lubrication, especially where a wood oil distributor is properly located within the bearing housing below the spindle. The 3-part bearing is extensively used on certain of such machines, namely: a half box is located at the bottom and to the rear of the spindle housing. The top construction consists of two adjustable bearing segments. By means of suitable thumb-screws these latter can be adjusted readily to meet lubrication and pressure requirements without the necessity for stopping the spindle. Production is, therefore, not interfered with in the making of any normal adjustment.

Flood lubrication has also been developed to a marked

degree, especially for the preservation of spindles. Mechanical or automatic circulation of the oil to the essential wearing parts can be admirably accomplished by means of a suitable chain driven pump which is driven from the wheel spindle. There must, of course, be adequate reservoir space with such a system to carry the requisite volume of oil and provide for proper settling. In many machines the hollow wheel slide is used for this purpose; as well, it serves as a housing for the oil pump.

Flood lubrication by means of oil circulation insures, perhaps, the greatest degree of operating cleanliness possible of attainment, for in addition to serving as a lubricant and coolant the oil will usually wash the entire system free of any accumulations of foreign matter. It is essential, however, that there be an ample quantity of oil in the system and sufficient volume in the reservoir to allow for precipitation or settling out of the majority of any foreign matter which may have been taken up during circulation.

In order to insure the maximum of protection from any grinding machine lubricant, it is absolutely essential to keep the lubricating system as free from foreign matter as is consistently possible, according to the operating conditions and bearing construction. There always is a possibility of entrance if impurities, especially where bearings may not be properly sealed. It is a matter of decided importance for we can realize that continued churning of abrasive foreign matter with oil and its passage through plain bearing clearance spaces or in intimate contact with highly finished balls and raceways will ultimately prove the ruination of spindle or main drive bearings and their respective elements.

As it is not always possible to effect the requisite degree of sealing or to depend upon the seal being in good working order at all times, grinding machine bearing lubricating systems should be flushed and cleaned at periodic intervals. The frequency will, of course, depend upon the design of the bearing, the type of seal, the lubricant used and the extent to which dust and dirt are present.

Systems served by sight feed oilers will in general require more frequent attention than ball bearings, due to the fact that their housings may be less carefully designed. With the former cleaning may be necessary or advisable at periods rang-

ing from every two weeks to every several months. With ball or roller bearings once or twice a year is sufficient, unless operating conditions are especially dirty. On the other hand, anti-friction bearings are more delicate from the viewpoint of construction, and therefore the lubricant should not be allowed to become as contaminated as is permissible with other types of bearings.

Circulating oiling systems possess natural advantages in that the flood of oil which is constantly passing through the bearings tends to wash out any grit, dirt, dust or metallic particles that may have gained entry. As a result, wear is reduced to a minimum, just as long as the oil in the system does not become so highly contaminated as to be unable to precipitate such foreign matter during its period of so-called rest. This flooding of bearings, by virtue of its washing action, naturally gives rise to gradual accumulation of foreign matter, therefore, the condition of the oil should be carefully watched and the system drained as soon as any excess of dirt becomes apparent.

For all normal conditions of grinding machine spindle operation it will be practicable to use a light to medium bodied straight mineral spindle or machine oil, the degree of refinement depending to a large extent upon the type of lubricating system. In sight feed oilers as used for spindle lubrication on many machines an oil from approximately 100 to 200 seconds Saybolt at 100 degrees Fahr. will adequately fill the clearance spaces and prevent abnormal vibration should these latter be comparatively high. Relative to the rate of oil feed, it is interesting to note that the Norton Co. recommends adjustment of sight feed oilers to deliver from about 7 to 10 drops a minute. It is practicable to use this same grade of oil for the spring-actuated wick-oiled bearings. In the ring oiling device, however, a somewhat heavier product will be necessary, the viscosity ranging from 200 to 300 seconds.

Grinding machine bearings served by circulating systems can normally function on an oil of similar viscosity as mentioned for the spindle bearings. Re-usage of oil by circulation, however, imposes a very important requirement upon any oil for such service. In other words, it must readily separate from water or other foreign matter, and not tend to develop emul-

sions to any extensive degree. For this reason attention must be paid to the degree of refinement of any oil under consideration. That is, an oil should be used which has been freed by filtration of those hydrocarbon constituents which may lead to subsequent emulsification, especially when the oil is agitated in the presence of air, and perhaps in contact with water or particles of metallic foreign matter. As a rule a viscosity range of from 100 to 200 seconds Saybolt at 100 degrees Fahr. will meet requirements.

For those other wearing elements in the average grinding machine, including reversing mechanisms with their essential gears, cams and bearings, an oil should be used which will meet the requirements of both hand and bath lubrication. This latter is prevalent in many reversing mechanism housings. The oil cup, however, prevails on the majority of the other general machine bearings. The duty involved is not severe. Therefore, a medium bodied straight mineral machine oil will, as a rule, serve the purpose satisfactorily, the viscosity range being from 200 to 400 seconds Saybolt at 100 degrees Fahr.

There may, however, frequently be a problem in the lubrication of flat bearing surfaces such as V's and table ways, due to the varied pressures which may be developed. For this reason the utmost care should be paid to selection of the oil to be used, and the extent of viscosity or body required. Lubrication of such surfaces can be accomplished by oil cups and suitable grooving of the ways, or by the installation of rollers located in depressions which can be kept full of oil. These latter are automatic, for at each passage of the slide the respective rollers carry a film of oil up to the surfaces of contact, in much the same manner as a ring-oiler would lubricate a plain bearing.

The viscosity range to meet the pressure conditions of slide operation must of necessity be wide. Oftentimes, on smaller grinding machines it can be as low as 300 seconds Saybolt at 100 degrees Fahr. On the other hand, larger machines such as those designed for the grinding of steel mill rolls may require a lubricant as heavy in body as a steam cylinder oil, the actual viscosity being perhaps as high as 130 seconds Saybolt at 210 degrees Fahr.

MAGNETIC CHUCKS

Magnetism is theoretically explained as a certain relative position assumed by the molecules or particles of iron, according to Herbert R. Simonds. To make this possible, it must be assumed also that each molecule itself is a magnet. Every magnet has a positive and a negative pole, or end. This is illustrated by the fact that if either the negative or positive poles of two magnets are brought together they repel each other, while if two opposite poles are brought together they are attracted and held together.

This property is found also in a helix, or coil of wire, through which a current of electricity flows. If a bar of iron is inserted in this helix, its molecules are drawn into position so that it also becomes a magnet. Such an arrangement is shown in Fig. 7, but the iron core has been bent into a U shape to bring the poles closer to each other. Here the electric

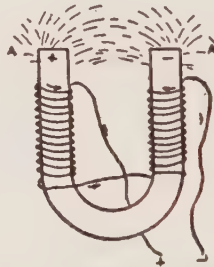


FIG. 7—MAGNETIC PRINCIPLE

current flowing continuously in the same direction (direct current) through the wire sets up a magnetic current at right angles to the flow of the electric current through the steel core. At the ends of the magnet poles this current passes through the air, which completes the circuit. When a piece of steel is placed across these poles, the magnetic circuit is completed more readily which holds the steel against the poles. As the resistance of air is about 100,000,000 times greater than that of iron, it will be appreciated that the closer the iron bar touches the poles, the firmer it is held.

Another point to remember is that only so many magnetic lines of force can pass through a certain area of iron, so that if a piece of iron, too small in cross-section, is placed across the poles, some of the magnetic lines of force radiating from

the poles can not travel through the piece. Under these conditions, the piece is not held as strongly as a unit through which all the lines of force can travel.

Any magnetic chuck is a readaptation of a plain horseshoe magnet, designed to bring its poles all in one broad, flat surface on which work may be placed for holding purposes. This principle is shown graphically in Fig. 8. The coils surround the cores which alternate in polarity, positive and negative, and it will be noted especially that the top plate is provided with inserted cores, insulated from the top plate frame, so that the

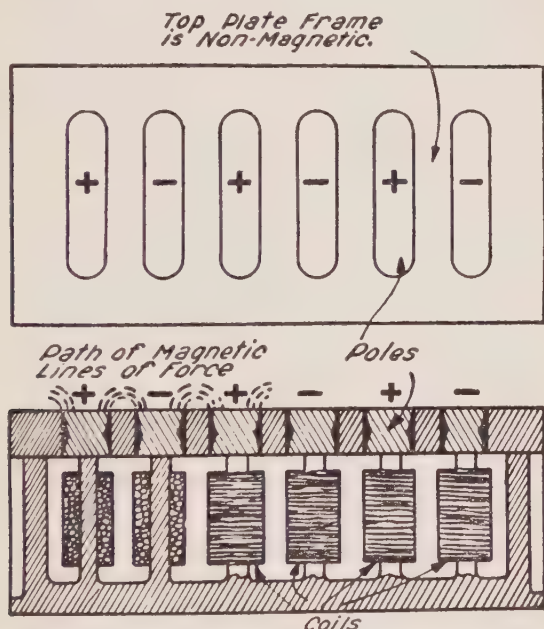


FIG. 8—OPERATING PRINCIPLE OF A MAGNETIC CHUCK

magnetic lines of force are conducted up to the work and do not become lost in the top plate itself. The plus sign designates positive poles, while the minus sign refers to negative poles.

While there are various designs of magnetic chucks, they embody but two fundamental differences. The oldest type embodies a single coil surrounding a single core, the poles of which are divided into numerous interlocking sections to distribute evenly the opposite polarities. The latter type is made up of numerous smaller coils, each one surrounding its own

individual core or pole which shortens and intensifies the path of the magnetic force lines.

When a chuck is loaded with small, but thick, pieces, the lines of magnetic force are dissipated. The other extreme involves thin pieces where the area of their cross-section is too small to permit sufficient lines of force to pass. In Fig. 9 is shown a steel cup whose flange is to be ground as indicated. As the bottom of the cup is too thin to allow enough lines of force to pass to hold the cup firmly, a steel disk is placed in the bottom of the cup to increase the path of the lines of force.

The auxiliary top plate is the most practical, but suprisingly least appreciated means, of increasing the usefulness of a magnetic chuck. It is simply a duplicate top plate that is fastened

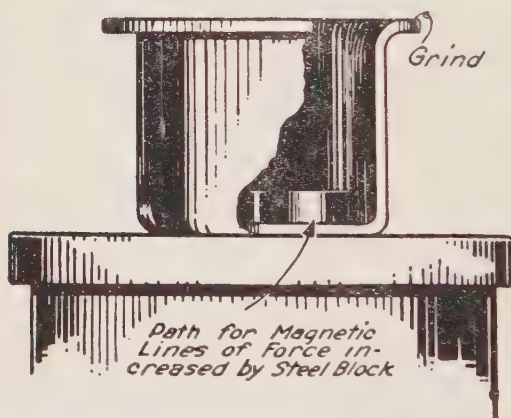


FIG. 9—HOLDING A THIN PIECE OF WORK EFFECTIVELY

on top of the standard chuck top plate and in which recesses for clearance, locating, and holding, are machined. Of course, this machining might be done on the top plate of the chuck itself, but this spoils the chuck for other work and the machine work, unless carefully done, is liable to open the top plate and allow water to enter, which will burn out the chuck. In the case of rotary chuck, care must be exercised in placing the auxiliary plate on the chuck so that the poles of both coincide. The reason for this is apparent, for if not placed in this manner, the magnetic lines will leak out into the top-plate frame and will not be conducted through the poles of the plate and into the work.

Fig. 10 shows the grinding of a thin paper cutter to a beveled edge. In this case, a special auxiliary plate was made because the poles of the chuck did not come close enough to the center to hold this small cutter. The plate was designed so that its poles on the side next to the chuck made contact with the chuck poles, while on the other side the poles were drifted, or offset, which caused them to come closer to the center of the paper knife. In grinding, instances often come where the work is so easily distorted that the irregularities on rough pieces are straightened out while the piece is in contact with the chuck. These irregularities, of course, reappear when the work is removed. To overcome this difficulty, various methods are employed. One is to place between the work and the chuck, the thickness depending upon the requirements. The paper forms a

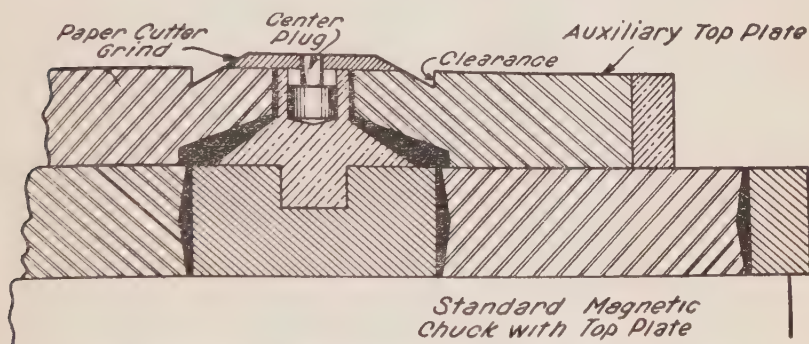


FIG. 10—TYPICAL ARRANGEMENT FOR HANDLING THIN WORK

slight gap between the chuck and the work. This gap, being insulated, resists the magnetic lines of force, causing them not to pull so strongly. Another plan is to place an auxiliary top plate on the chuck so that the poles do not coincide exactly. In this way, the magnetic lines of force leak, or spread out, over the top plate and reduce the holding power.

Magnetic chucks, in common with all tools, have their peculiar troubles. In many cases, however, they are blamed when the trouble is due entirely to electrical conditions outside the chuck. Many shop electricians are guilty of returning magnetic chucks for repairs when the trouble is elsewhere. The following are a few suggestions that will eliminate needless delays:

A weak chuck is caused by the voltage being too low. The

generator brushes may make poor contact. The work may be so rough or uneven as to cause air gaps between it and the chuck. The work may be nonmagnetic. Steel dust may collect between brushes and collector rings on rotary chucks.

A dead chuck is the result of a short circuit, in the connecting wires, loose connections, or by the brushes not making contact on the chuck collector rings. If none of these causes are found, the chuck itself is short-circuited or burned out and should be returned for repairs. One section of the chuck may be weak or dead. When in this condition, the chuck itself is usually wrong and should be returned for repairs.

If the chuck blows out fuses, the generator is speeded too high. Too many chucks or other apparatus may be on the circuit, drawing too much current. A short circuit in the chuck or connecting wires will also cause this trouble.

Water in the chuck is frequently caused by wearing or resurfacing of the top plate until it is so thin that water leaks in through the screw holes by which it is fastened. If a chuck is used in a vertical position without protecting the joint between the top plate and body, water may leak in. A break in the lead wire protecting tube is also a cause of this trouble. The top plate may have been removed and not properly replaced.

Whenever trouble occurs, the operator should make sure that outside conditions are correct. If trouble appears to be with the chuck, it should be returned to the manufacturer for repairs. Five minutes work will often put a chuck in order when an electrician unfamiliar with the work will make it necessary to replace all the coils.

Many times there is a doubt as to whether a demagnetizer is necessary. All chucks are provided with demagnetizing switches which demagnetize the chuck so that the work is readily removed. This switch also demagnetizes the work to a certain extent, but where all magnetism must be removed, as is the case with gages, dies, pawls, etc., a demagnetizer is necessary. Hardened steel retains magnetism to a greater extent than soft steel or cast iron and large pieces more than small. There are two types of demagnetizers, the hollow-coil and the plate type. The latter is the older design wherein the work is demagnetized by sliding it across two plates. In the former type the work is held or dropped through an opening in the demag-

netizer and is especially suitable for irregular and bulky work.

To what an extent a magnetic chuck may be utilized is difficult to determine without experiment, but if care is exercised in trying out various applications, always keeping in mind the principles of magnetism, worth-while results can be obtained.

The rotary magnetic chucks supplied with Blanchard surface grinding machines differ radically from other designs. The chuck body is a solid disk of forged steel in which are machined on one side large concentric grooves to receive the coils, and on the other side numerous small grooves which are filled with hard brass. This design leaves a continuous layer of steel extending under the entire face of the chuck making it waterproof indefinitely. The coils are form wound, impregnated with an insulating compound and are sealed in place. The working face is composed of steel and brass in alternate rings. So close is the spacing of the steel poles that a piece of work as small as a twenty-five cent piece will touch two or more poles, no matter how placed.

METALLIC ABRASIVE MANUFACTURE

Crushed iron and steel materials used by the foundry industry in this country 15 years ago did not exceed 200 tons annually but with extensive improvements having been made in the design of cleaning equipment during this period, however, the volume of steel shot and grit used for abrasive purposes now totals several thousand tons a year. One producer alone ships over 7000 tons of this material annually. Large quantities of crushed steel are used for sawing and rubbing stone, marble and onyx. Its resistance to pulverization serves to produce uniformity in the grinding of optical lenses, and, hence, the consumption of crushed steel by this industry assumes attractive proportions. Locomotive builders also make use of this material for facing surfaces together, such as in the case of air joints, throttle valves, etc.

Crushed steel is made from high-carbon and crucible sheet steel. In preparing it for commercial use the steel is specially treated to impart brittleness and in this condition the material is crushed by special designed equipment operated electrically. The size of the material as it leaves the crusher ranges from 2 to 200 mesh. After screening into various sizes each batch

is heat treated and then separated into 25 sizes ranging from 20 to 200 mesh. Sizes from 70 mesh upward are screened on silk bolting cloth and the finer sizes in powder form are used as one of the ingredients of steel cement, in the manufacture of various chemical compounds and for making fireworks' sparklers. In the latter connection several hundred tons are used annually.

A product, known as steel shot but which merely is chilled cast iron, also finds extensive use in foundry practice. In the process of manufacturing steel shot the highest grade of raw material is used, including selected scrap and charcoal iron. These are melted in a cupola which is equipped with numerous runners. During the casting period the metal is separated into small spherical globules by the action of high-pressure steam or heated compressed air directed against the stream and in this form the metal is blown into a tank of water and cooled. The shot, made brittle by the rapid cooling, is heat treated to impart a temper of hardness and then graded by mechanical means into 15 sizes which range from 4 mesh down to 90 mesh.

Steel shot is used for sawing, grinding, polishing or rubbing stone, marble or granite, as an abrasive for core drilling and for making burnishing pebbles. The finer sizes are used principally as an abrasive for sand blast purposes. Coarse material left on the 4-mesh screen is granulated by special designed crushing equipment and in this form is known in trade parlance as angular steel grit. After the crushed material is heat treated, to impart the qualities of toughness and durability, it is graded into 15 sizes ranging from 7 to 100 mesh and is then ready for blasting forgings, castings, tire rims, stampings, pressed steel parts, stone monuments, etc. Crushed steel, steel shot and angular steel grit are shipped in burlap bags with a holding capacity of 100 pounds.

MATHEMATICAL FORMULAS

The following formulas pertaining to abrasive engineering are given in simple arithmetic so that they can be used readily by those not possessed with a knowledge of higher mathematics:

To find the circumference of a circle—Multiply the diameter by 3.1416.

To find the area of a circle—Multiply the diameter by itself and the result by 0.7854.

To find the volume of a cylinder—Multiply the area of the base by the height.

To find the peripheral speed of a grinding wheel—Multiply the diameter of the wheel in inches by 3.1416, divide by 12 and multiply by the number of revolutions per minute.

To compute the work speed of a given piece in feet per minute—Multiply the diameter in inches by 3.1416, divide by 12 and multiply by the work revolutions per minute.

PULLEY-SPEED RULES

The following data pertaining to the calculation of speeds and diameters of pulleys was compiled by the Abrasive Co. Given in simple arithmetic, the rules are valuable and easily comprehended:

When the proposed speed of the grinding wheel is known, to find the countershaft speed:

Rule—Multiply the number of revolutions per minute of the grinding spindle by the diameter of the pulley and divide the product by the diameter of the driving pulley on the countershaft.

Example—The driving pulley on the countershaft is 20 inches, the pulley on the wheel spindle is 8 inches and is to make 800 revolutions per minute. How many revolutions per minute must the countershaft make?

$$800 \times 8 \div 20 = 320 \text{ revolutions per minute.}$$

When the speed of the countershaft is known, to find the diameter of the pulley to drive the grinding wheel spindle:

Rule—Multiply the number of revolutions per minute of the grinding wheel spindle by the diameter of its pulley and divide the product by the number of revolutions per minute of the countershaft.

Example—The pulley on the grinding wheel spindle is 6 inches in diameter and should make 1400 revolutions per minute. The countershaft revolves at 650 revolutions per minute. What should be the diameter of the driving pulley on the countershaft?

$1400 \times 6 \div 650 = 13$ inches, the diameter of the driving pulley on the countershaft.

With the proposed speed of the countershaft known, to find the diameter of the pulley to install on the line shaft:

Rule—Multiply the number of revolutions per minute of the countershaft by the diameter of the tight and loose pulleys and divide the product by the number of revolutions per minute of the line shaft.

Example—A line shaft running at a speed of 231 revolutions per minute is required to drive a countershaft at a speed of 660 revolutions per minute. The driven pulley on the countershaft is 7 inches in diameter. What should be the diameter of the driving pulley on the line shaft?

$7 \times 660 \div 231 = 20$ inches, the diameter of the pulley on the line shaft.

In general, the diameter of any driven pulley multiplied by its speed in feet per minute always equals the diameter of the driving pulley multiplied by its speed in feet per minute.

REVERSING ELECTRIC GRINDERS

Occasionally an operator desires to run an electric bench or floor grinder in the opposite direction for which it was designed. According to the James Clark Jr., Electric Co., Inc., no changes are necessary with the exception of the electrical alteration in the motor wiring that are required to make the motor operate backwards. Other factors are involved, however. All motors can be reversed, but to those who have never tried reversing a grinder it is well to give a warning not to attempt it.

Many have noticed, in the case of a bench grinder or floor grinder, that the clamping nut on the right-hand end has a right-hand thread, while the nut at the other end of the spindle has a left-hand thread. To one who does not know the reason for this, it probably seems an odd thing for a manufacturer to do. A designer chooses the lead of a grinding spindle thread so that any slippage of the grinding wheel on the shaft will cause the nut to tighten.

When a motor is reversed, the nuts, outside flanges and wheels occasionally drop off the end of the shaft immediately. This is due to the fact that grinding wheels have considerable inertia, or fly wheel effect. When the shaft accelerates during

the starting period, the inertia of the wheels gives them a tendency to lag behind. This produces a slippage which moves the outside flange and the nut slightly, and if the shaft is running in the wrong direction, this, of course, will back the nut off.

The upshot is that grinding machines must not be reversed without providing them with new spindles, threaded on the ends in a direction reversed to what they were previously. Even placing a lock washer between the nut and the outside flange does not make it safe. There are some grinding machines which do not use a threaded spindle. They are very rare, however, and it is consequently safe to establish as a rule the fact that grinding machine must not be reversed.

RUBBING BED

A cast iron disk varying in diameter from two to 15 feet or more and used for finishing flat surfaces, principally on stone such as marble. The disk is arranged horizontally and revolves at speeds ranging from 10 to 30 feet per minute at the periphery. The work is located against cross arms to prevent it turning while its weight keeps it in grinding contact. Various abrasives are used on rubbing beds, always with a liberal water supply. Sharpening stones, and in some instances the sides of small grinding wheels, are finished flat on rubbing beds. In this instance carbide of silicon is used as an abrasive medium.

RUBBING BRICKS

Rubbing bricks are made in various shapes and sizes of natural or manufactured abrasives and used for various purposes such as cleaning castings, rubbing down cement or concrete surfaces, etc. Small rubbing bricks often are termed abrasive sticks. The only difference between a rubbing brick, or stick, and a sharpening stone is that the former is not finished after it comes out of the vitrifying kiln, whereas the latter is smoothed on all sides on a rubbing bed.

Special shape bricks are used for a diversity of purposes. Those with angular grooves across their faces are used extensively for rubbing concrete surfaces. Perforated bricks made of manufactured alumina are used for rubbing varnish on patent leather. A potter's cutter is a comparatively thin rubbing brick

used for smoothing *biscuit ware*. Small square, round and triangular shapes are called *sticks*, although they generally are listed under the general heading of sharpening stones.

SALVAGING ABRASIVE MATERIALS

Some years ago, when the output of manufactured abrasives was under the control of two companies, carbide of silicon and manufactured alumina wheel stubs had a market value. They were bought up in 100-pound lots and crushed, the grain thus produced being treated and marketed as recrushed grain. Now that artificial abrasives can be purchased by anyone on the open market, the demand for recrushed grain has decreased. In passing it may be well to state, however, that recrushed grain should have a market value for impregnating the so-called safety tile as used for flooring. Where safety cement surfaces are laid, the recrushed grain is mixed with the upper coating.

Grinding wheel stubs sometimes are used to advantage in place of rubbing bricks for cleaning castings, etc. Also they are used in tumbling barrels. We have heard of them being set in plaster of paris in a cast iron holder for finishing stone surfaces. Broken wheel stubs can be used for a filler in cement work to take the place of stone where it is cheaper to work them off in this manner than to dispose of them otherwise. The bushings in wheel stubs have a market value as scrap lead. These bushings also are used in tumbling barrels in steel foundries to polish castings.

Where polishing operations are carried on to any extent, the abrasive grain carried away through the exhaust pipes or collected otherwise has a commercial value. The grain is boiled to remove the glue and mixed in with a batch of new abrasive grain for setting up polishing wheels or belts. Care must be exercised, however, not to mix coarse reclaimed grain with new material of a finer grit as such a mixture would leave undesirable scratches.

In every coated abrasive manufacturing plant where special shape materials are made, a large amount of waste products accumulate in the shape of cuttings. In cases where small pieces of abrasive paper or cloth are used, if these cuttings can be purchased, a distinct saving sometimes can be shown.

SETTING UP GRINDING MACHINES

First examine the grinding machine builder's erection plan carefully to make sure that all necessary specifications have been followed. Special attention should be given to locating the grinder properly under the overhead works, if any are used. A cement foundation always is preferable, but in cases where a machine must be set on a wood floor especially above the first story, it is a good plan to locate it near a wall or a supporting column. This will help to overcome vibration which always is a detrimental factor in grinding machine operation. Be sure that the machine is leveled accurately both ways. The base can be leveled by driving wedges under it. However, in setting down the foundation bolts care must be exercised not to throw the bed out of line. If the machine is to be set on a cement floor, after it is leveled a dam of putty or clay should be built around the base on both the inside and outside. Leave a number of vents in the outside dam and pour the space under the machine between the two dams full of molten sulphur. This will result in a satisfactory foundation.

SPINDLE ADJUSTING

Due to the fact that a wide variety of grinding machine spindle designs are in use, it is impossible to give specific instructions for their adjustment. In general it can be stated that the spindle of any grinding machine should fit its bearings snugly to avoid play, which would result in chattering. In taking up the subject of grinding and polishing stands, several varieties of bearings are found, such as bronze, babbitt, ball and roller. Bronze and babbitt bearings on the types of machines in question are adjusted by rescraping them to fit and setting up the box caps by taking out liners or removing a slight amount of metal from the clamping surfaces. The scraping should be performed accurately by a skilled machinist and the bearing set up just tight enough to *drag* slightly when turned by hand. Ball and roller bearings on the types of machines used for rough grinding and polishing seldom are provided with adjustments so the only remedy for a loose bearing is to install a new one. Fortunately, these bearings are not expensive. If the machines are fitted with the type of

taper roller bearings commonly used in automobile construction they can be adjusted readily. The use of such bearings is to be recommended.

In adjusting the spindle bearings on a precision grinding machine, the general rule is to have the bearing tight enough so that it warms up when the machine is in use. The operator never should attempt to adjust a bearing with which he is not thoroughly familiar for he is liable to do more harm than good. A good plan is to refer to the instruction book that is provided with the machine. The directions should be followed explicitly and carefully.

VACUUM CHUCKS

The so-called vacuum chuck consists of a hollow rectangular box with openings at the top over which the work is placed. The air is exhausted by a pump so that atmospheric pressure is utilized to hold the work in place. These chucks are useful for grinding non-metallic substances such as fiber glass, stellite, wood, etc. They are used principally on surface grinding machines.

SECTION XII

MISCELLANEOUS ABRASIVE OPERATIONS

Under this heading are grouped a number of interesting and important abrasive operations arranged alphabetically as follows:

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MISCELLANEOUS ABRASIVE OPERATIONS

AGATE GRINDING

In one prominent shop in New York a tin wheel is used with abrasive tripoli and this practice is quite general. In some instances wood wheels are used and again pumice stone is often substituted for tripoli. Tin or wood wheels are operated horizontally. They are 12 inches in diameter and 1 inch thick and are operated at speeds ranging from 300 to 400 revolutions per minute. Lead wheels also are used for roughing operations. They are moistened with water and impregnated with No. 120 carbide of silicon. Sometimes vitrified bond carbide of silicon wheels in 80 grit are used for rough grinding. In Germany, where the agate industry flourishes to quite an extent, the gems are cut on large grindstones.

AUTOMOBILE BODY FINISHING

Abrasive processes followed in the finishing of automobile bodies consist of rubbing down carefully successive coats of filler, paint, varnish or nitro-cellulose lacquer to present a smooth surface. Each coat must be brought to a level surface or otherwise the next coat cannot be laid level. The process generally is lengthy and painstaking where a high-grade finish is essential. Methods differ in various plants. The process employed where paint and varnish is used is as follows in a representative plant:

First, all surface imperfections on the bare metal are removed with abrasive cloth in $1\frac{1}{2}$ and $11\frac{1}{2}$ grits. Pronounced irregularities, however, are filed smooth. Then the body is cleaned thoroughly as paint will not stick to a dirty surface. Aluminum bodies are washed with a volatile solution, while steel bodies are gone over with a preparation that removes rust, grease, etc. If the rust is not removed, the paint will peel.

Next follows the first priming coat which is a lead composition of a dark brown color. This coat is brushed on bodies, although fenders, radiator covers, aprons, etc., are sprayed. This operation is technically termed *priming*. After the body has been dried for 24 hours, a coat of flat lead is applied. This is a slate color. The next operation to follow is called *glazing*.

It consists of filling slight imperfections with a special composition called glazing compound, which resembles white-lead putty. This material is applied with putty knives. In color it is lighter than the preceding coat so that the glazed portions can be seen readily.

The body is now ready for the application of five coats of *rough stuff* laid on successively with a brush. The coats are applied alternately, vertically and horizontally, each coat being dried for 24 hours before the application of the next. Each coat is rubbed wet with hone and pumice gangs. Before the gang-rubbing operation, however, abnormally high spots are brought down with No. $\frac{1}{2}$ abrasive cloth. Five coats of rough stuff are necessary as one coat often is rubbed through in spots.

The body now is ready for its first coat of color. This coat is of a composition that dries *flat*, that is, without luster. Colors are applied with a brush, although white paint frequently is sprayed in place. The next coat is the so-called *color varnish*, that is, a high-grade varnish carrying a pigment to impart the color. After drying this coat is *oil sanded* with No. 4/0 flint paper. The paper is soaked in linseed oil before using. Three more coats of color varnish next are applied, each one being dried 24 hours and rubbed down with pumice powder and water. The body then is given a coat of clear varnish which after drying is rubbed with pumice powder and rotten stone, both being applied with water.

The car now is assembled and given a road test after which it is washed with great care. Then the body is again rubbed with pumice and rotten stone. Next follows striping if the specifications call for this. Finally, the last coat of varnish is applied. This is a clear material of English composition. The varnishing often is done in a dust-proof room and dried for 24 hours in the dark.

The American Glue Co. furnished the following data pertaining to the finishing of lacquered automobile bodies:

The advent of nitro-cellulose lacquers completely changed the methods of automobile manufacturers in painting their cars. As is always the case in a revolutionary movement of this kind, there was a great deal of seesawing back and forth in materials and details of operation before the big production

shops settled on a fairly standardized method for applying lacquers. The changes were so rapid and confusing that the whole subject was more or less treacherous ground for the automobile refinisher. Today, however, the experience of production shops has been sufficient to allow lacquer manufacturers to make definite recommendations on materials and methods without fear of an overnight change.

The experiments and testing on different kinds and types of sandpaper were just as confusing for a long time. And today we are still finding many refinishers who are not yet properly posted on the most economical sanding methods. With a view toward correcting this condition, there is presented here a set of rules for refinishing automobile bodies with lacquer. Attention is especially invited to the use of the less expensive glue bond (finishing) papers in certain operations where many have believed a waterproof paper necessary.

1.—Removal of old paint. There are many chemical preparations on the market which allow the easy removal of the old varnish coats, or they may be burned off with a gasoline torch. It is essential that this be a complete job and the metal body be brought up to a bright finish with a fine grade dry paper. The exact number to use will depend on the condition of the body, amount of rust, etc. In general, No. 150 finishing paper is recommended; which may be replaced by the finer No. 180 or the coarser No. 120 as necessary. Sometimes it is convenient to use gasoline in connection with this sanding but that does *not* require a waterproof paper, as a glue bond is impervious to a petroleum product.

2.—The primer coat is then applied to the metal and, where necessary, spot sanded with this same No. 150 finishing paper.

3.—The surfacer coat which follows the metal primer frequently receives insufficient attention simply because it is an undercoat. Most failures in lacquer finishes are directly traceable to a poor surfacer coat. Lacquer does not fill up and conceal imperfections. Instead, it acts as a high-powered glass and magnifies them. The surfacer must be sanded absolutely smooth and free of scratches. Surfacer sanding is essentially a water-wet operation and waterproof paper must be used. Two separate sandings are required. First wet the body with

water and sand it with No. 220 waterproof paper. The surface should be kept well slushed with water while sanding. After removing the roughness, water sand again with No. 280 waterproof paper. Every scratch should come out in this operation. After going over the whole body, examine carefully for any scratches that may possibly be left and get them out by water sanding again with No. 320 waterproof paper.

4.—The lacquer coats. The number of these depends, of course, on how high-priced a job is being done. The lacquer manufacturer gladly gives the necessary information. Refinishers doing a very high quality job sand between the coats of lacquer, while the cheaper jobs are only sanded on the final coat. Wet sanding is best on lacquer but not water-wet. A rubbing oil consisting of a kerosene base emulsified so as to be thinned out with water may be used and in that case a waterproof paper is required. A more economical wet sanding may be done with a mixture of ordinary cylinder oil and an equal quantity of gasoline or a slightly larger quantity of kerosene. The great advantage here is that, while a watered-oil requires waterproof paper, the straight petroleum mixtures work well with the much lower priced glue bond (finishing) papers. With the watered-oil use No. 320 waterproof paper. The still finer No. 400 grade may be substituted here and on very high quality jobs is perhaps more desirable for the final coat sanding. Just as perfect a finish can be obtained with the oil and gasoline, or oil and kerosene, mixture using the more economical glue bond paper—No. 320 or No. 400 finishing paper. In either case the oil solution is smeared on the body and the paper dipped in it before sanding. Sand carefully with light pressure over the entire surface until the orange-peel effect is removed. Then wash the body, dry with a chamois, and apply the polish and wax finish recommended for your particular lacquer.

BURNISHING PRACTICE

Burnishing as applied to smoothing metal surfaces may or may not be an abrasive action, although it is often considered as such. Burnishing can be performed by hand or automatically. An excellent example of hand burnishing consists of highly finishing steel spectacle frames before they are colored. The frame first is smoothed very carefully with flour

emery paper. Then it is burnished with a hand burnishing tool; a hardened steel blunt instrument, highly polished. Such burnishers are made of old half-round files about four to six inches long. As the tool is passed over the work it imparts a high gloss, even under ordinary pressure.

Automatic burnishing is performed in revolving burnishing barrels in which the work is placed with burnishing agents such as steel balls or other mediums. Thus this process is closely allied to that of tumbling. Frederic B. Stevens, gives the following pertinent information relative to burnishing balls:

The full barrel will operate satisfactorily with fewer balls in proportion to the work than a half-full barrel. This is because the work is all the time completely surrounded by the balls. There is no floating, the balls fill all the voids between the separate pieces of work. The right size of balls to use for any given job is judged by allowing a ball to rest in the sharpest corner or crevice of the work. Balls being round, it is easily understood that a small ball will rub closer to the angle of a sharp corner than will a ball of larger diameter. Regardless of the size of the ball, the bearing or rubbing surface is almost a pin point of contact. Two balls $1/16$ -inch in diameter will therefore offer two points of contact where a $1/8$ -inch ball would offer only one. For some classes of work a large ball seems to be the most effective. Other work turns out better with a small ball, while still other work may show the best results with two or even more sizes of balls mixed. This is a matter which has to be determined by the nature of the work.

Burnishing balls need not be perfectly round; even a flat spot offers no objection and their accuracy as to dimensions is of no consequence. To burnish well, they must be hard and as smooth as it is possible to make them. The culls, or inaccurate balls turned out by manufacturers of bearing balls, furnish an exceptionally good and inexpensive supply. Also, to meet the demand for ball burnishing, certain manufacturers are making balls for the purpose. These special balls are hard, smooth and highly polished, and as slight variations in size do not matter, they can be produced at a reasonable cost.

In handling these balls, they are usually referred to in peck quantities. Work is referred to in the same manner. A peck of work placed in the ball burnishing machine will call for

an equivalent quantity of balls. The balls most often used are 1/16, 1/8 and 1/4-inch. Approximately one peck of balls, regardless of size, will weigh 100 pounds. The 1/16-inch size will run close to 20,000, the 1/8-inch to 3200 and the 1/4-inch to about 450 per pound. One peck of 1/16-inch balls, therefore, represents about 2,000,000 separate little burnishing tools, each one furnishing several points of rubbing contact.

CARBON GRINDING

The principal use for abrasive working carbon is in cutting up slabs for various purposes and the radial grinding of commutator brushes. Machines used for cutting slabs look like ordinary saw benches fitted with thin elastic wheels instead of saws. In grinding commutator brushes with a disk wheel it is necessary that the wheel be of the correct diameter to impart the desired radius. This, however, can be accomplished readily by varying the relation of the angles between the wheel and the work-carrying fixture axes. Carbide of silicon wheels are used for carbon grinding.

CHINESE ABRASIVE PRACTICE

Abrasive practice in China consists principally of gem cutting and tool sharpening. Gems of various kinds are cut on iron or steel wheels about 20 inches in diameter and 1-inch face, with moist sand as an abrasive. The sand is kept in a box under the wheel. It is applied with one hand while the artificer holds the work in his other hand, sometimes in a simple holder. Several grades of sand are used. One is flint powder obtained in the Northern Provinces. Comparatively soft gem stones are cut with a variety of red sand (probably a variety of garnet) found in the Honan province. A variety of so-called *black jewel sand* is used for cutting hard stones. What is known to the Chinese gem cutting trade as *diamond dust* is a fine black abrasive produced in the United States. It is said to resemble carbide of silicon. In the Southern Provinces a number of varieties of sand are used, each kind being divided into many grades. Comparatively few manufactured grinding wheels are used in China as knives, chisels and other edge tools are sharpened on natural grindstones or flat slabs. Natural stones also are used for grinding peanuts, rice, wheat, etc. These stones, which substitute ordinary burr

stones as used in the United States and Europe, are operated horizontally, one the bed and the other the runner stone. According to Chinese practice the grooves in the bed and runner stones radiate in opposite directions.

Metallic surfaces are polished with sand instead of with emery or manufactured abrasives. For fine polishing operations the abrasive is set up on leather straps. Due to the fact that Chinese labor is very cheap and abundant it may be many years before modern abrasives will be introduced generally.

CLEANING ROOM PRACTICE

Cleaning room practice differs in various foundries, but in each instance the main object should be to have the castings progress through the cleaning room with as little backtracking as possible. In cleaning room practice in gray iron foundries, the first step is to remove cores and core wires. Then the castings should be rattled or sandblasted to remove superfluous sand. As a rule small castings are rattled while large ones are sandblasted. In some instances, however, comparatively large castings can be rattled economically. In this category are cylinder blocks, heads, etc. They should be packed carefully with special filler pieces interposed as these large castings must not be tumbled about indiscriminately. After rattling or sandblasting the castings should be inspected carefully and if slight imperfections can be repaired by welding, this operation should follow.

Large castings are ground under swing-frame grinders, while small ones are ground on hand grinders. Carbide-of-silicon wheels are used universally for grinding gray iron. In foundries where continuous production is the rule, it is an excellent plan to provide an endless conveyor belt between a double row of floor grinders so that the belt is back of the machines. Thus as the castings are ground they are thrown on this belt where they are conveyed to a sorting table. With an installation of this kind the castings can be handled rapidly.

The tumbling barrels and the grinding machines should be equipped with an adequate system for carrying away the abrasive dust. A foundry is not a tidy place under ideal conditions so that all means possible should be taken to reduce the dust hazard to a minimum.

MISCELLANEOUS ABRASIVE OPERATIONS

In plants where automobile engine castings are made, careful inspection is necessary. Manifolds, cylinder blocks, etc., must be subjected to a water pressure test, while pistons must conform closely to gages provided for their inspection. After the final test the castings are taken to the shipping floor, which preferably should parallel a railroad siding.

Malleable iron grinding procedure is somewhat different. The castings can be ground before or after annealing. If they are ground before annealing, carbide-of-silicon wheels should be used. If ground after annealing, alumina abrasives will show better results. After the ground castings are annealed they present even surfaces which adds materially to their sales value. Again, if the castings are ground before annealing the surface texture is the same throughout after the annealing process is complete. In some instances it is practicable to grind the castings to advantage after annealing.

In steel foundry cleaning room practice, the castings first are sandblasted and the gates and risers removed by flogging or by a cutting torch. Then the castings are ground, inspected, annealed and rattled. The procedure differs in various plants. Wheels for grinding steel castings must be very durable and for this reason emery often was preferred in times past. At the present time, however, the manufacturers of alumina wheels have made great progress in adapting products for this work.

Brass and aluminum castings should be ground with carbide-of-silicon wheels. The gates preferably are removed by a sprue cutter or a metal band saw. The grinding machines should be equipped with an adequate dust removal system for the abrasive dust that lodges in the exhaust lines and in the dust arrester is heavily charged with metal that can be salvaged. According to some authorities, a dust disposal system in a brass or an aluminum foundry will pay for itself in a few years in the metal reclaimed.

Wheels in foundry cleaning rooms are vitrified or rubber bond. The former should be operated at speeds ranging from 5000 to 5500 surface feet per minute; the latter at speeds ranging from 9000 to 12,000 feet per minute. A rubber bond wheel must be operated at a high peripheral velocity to show efficiency. Such wheels should be used only on substantial grinders. In everyday cleaning room practice it is a good plan to keep the

peripheral speed of the wheels as constant as possible. This is provided for in many foundries by changing the wheels from one stand to another as they wear down. Each successive grinder, of course, must be run at a slightly increased speed. To prevent the mounting of wheels that are of too great a diameter for the spindle speed it is a good plan to provide guards of a diameter that will not permit the mounting of wheels that are too large for a safe surface speed.

COMMUTATOR DRESSING

Electric motor and generator commutators generally are dressed occasionally with fine-grit sandpaper or garnet paper. Nos. $\frac{1}{2}$ to 00 are used, depending on the size of the commutator. As a rule but little dressing is required. For example, the commutator on an automobile generator will run for several months without attention. The commutators of large motors, however, used in industrial plants should be smoothed off occasionally, at least once a week. Too much attention, however, is a detriment as the continual abrasive action wears the copper surface unduly. A special stone, called a commutator stone, also is used for dressing these members. It is made of a natural sandstone or of a manufactured product, such as carbide of silicon. When a commutator is worn badly the only remedy is to take out the armature shaft and mount it between centers in a cylindrical grinding machine where the commutator can be dressed level. A carbide of silicon wheel in a medium grit and grade should be used.

CORE CUTTING AND GRINDING

Round, square and hexagon foundry cores are made up in pieces of various lengths and cut and trimmed to size as wanted. They are cut on a cutting off machine and if any other grinding is necessary it is done on an ordinary grinding wheel. The cores used in making automobile engine cylinders must be very accurate as thin section metal is involved. Thus, if these cores warp out of shape to an appreciable degree they are too inaccurate for close work. They are ground level and true after baking by passing them under a cylinder wheel which is mounted on a vertical axis. Carbide of silicon in 16 to 24 grit is used. Generally a special machine is improvised for the purpose.

FIRE-BRICK GRINDING

Fire bricks of various kinds often are ground where it is necessary that smooth surfaces be generated for making fits, etc. Side surfacing machines are excellent for this purpose. In many instances, however, makeshift appliances are used. In general carbide of silicon gives good results on this work. When possible the work should be performed wet to carry away the dust and to keep down the frictional heat.

GLASS GRINDING

Glass grinding is an important branch of abrasive practice. It includes a number of interesting operations on glass for everyday uses. Due to its hard nature, glass cannot be worked without the use of abrasive materials of various kinds. Plate glass, such as used for store windows, automobile windshields, etc., must be ground and polished on both sides. The glass is cast on a table and then passed through a lehr where it is annealed. Grinding is performed on large circular iron tables about 20 feet in diameter. These tables revolve at an approximate speed of 60 revolutions a minute. Above the table is fixed a crossrail on which two iron shod runners are located. They are circular disks and their function is to carry abrasive material over the surface to be ground, making the grinding contact at the same time. The plate of glass is cemented on the table with plaster of paris, being bedded in place. It is also prevented from slipping by wedges placed along its sides. As the glass revolves the action causes the runners to rotate also as the peripheral speed at which the glass passes under them varies. Sharp sand and water is used for the first grinding operation. This abrasive is known as silica sand. Next the surface is smoothed with fine emery and water. Then the sheet of glass is turned over and the other side rough and finished ground. The final operation consists of polishing with felt-shod rubber disks placed on the runners. The abrasive used is rouge. Grinding operations reduce the sheet of glass 40 per cent in thickness.

Glass beveling is another important branch of glass grinding. Glass edging, that is grinding the edges of plate glass smooth for automobile windshields, etc., is performed in much

the same manner as beveling. Plate glass generally is beveled by hand on a device called a beveling mill. This is a cast iron disk about 30 inches in diameter operated at a speed of 450 revolutions per minute. The abrasive agent is No. 70 carbide of silicon applied with water. In grinding a bevel, the operator first *backs up* the surface, that is, he holds the glass at right angles with the mill so that the edge will be finished flat. Next the glass is held on the mill at the correct angle to generate the necessary bevel. The abrasive here is No. 70 carbide of silicon. The following operation is called *emerying* as emery formerly was the abrasive used. It is performed with No. 140 grit material. This grain generally is a reclaimed product from the roughing mill. The next operation is called smoothing. It is performed on a natural sandstone called a Newcastle stone. This stone is mounted horizontally over a wood table. The grinding is done wet and the object is to remove the fine scratches left in the emerying operation. The Newcastle stone is 30 inches in diameter and is operated at a speed of 250 revolutions per minute. *White wheeling* follows. It is done in a poplar wood wheel 40 inches in diameter, 4-inch face operated at 400 revolutions per minute. The abrasive used is No. FF pumice and water which is splashed on the wheel by a paddle mounted in a deep box. Buffing on a felt faced wheel follows, the abrasive being rouge and water. Numerous improvements have been instituted for grinding glass for automobile windshields, especially for finishing the edges. For instance, the edges of the glass are first ground on a mill as previously described and then finished on a manufactured alumina wheel which has seven depressions formed in its face. The edges then must be chamfered. This is done on a beveling mill, much after the manner in which ordinary plate glass is beveled. The final operation is polishing on poplar wood wheels with pumice and water.

Glass cutting is an interesting operation entailing no end of care and attention. In cutting an ornamental punch bowl, for example, thousands of intricate cuts must be put in while the operator guides the work by hand. Cut glass is made in two varieties, that is, it is cut from plain or figured blanks. As its name implies, a plain blank carries no design while a figured one is formed in a mold to impart the design to guide

the operator. Plain blanks are used by shops that wish to put out exclusive patterns. Figured blanks are employed when it is desirable to turn out a large amount of material for the cheaper class of trade. The first step when working with plain blanks consists of marking the desired pattern on glass with a red pigment. The marker often is a cutter also. This marking is free hand work and consequently is sketchy. The design then is roughed out on a roughing mill. This appliance is a wrought iron disk about from 18 to 24 inches in diameter, with a beveled face. It is mounted on an arbor or spindle which has tapered ends that fit in depressions in wood bearing blocks. A pulley is provided on the spindle for a one-inch flat belt. The abrasive used is No. 60 carbide of silicon and water which flows on the mill. A trough is placed underneath to catch the material that runs from the work so that it can be used over and over again. Mills as small as six inches in diameter are used for making some of the finer cuts. An 18-inch mill is run at a speed of 200 revolutions per minute. In cutting the design, the operator is guided only by his eye and, as may be imagined, skill of a high degree is necessary. If the work shows a tendency to chatter it is overcome by placing a wad of putty on the glass to absorb the vibration. The operation that follows is called smoothing. It is done on beveled wheels made of natural stone or from manufactured abrasives. The natural stones used are the so-called Craighleith in both white and black varieties. When a manufactured abrasive is used it is aluminum oxide. Manufactured wheels usually are 120 grit and medium grade. Most present day cut glass receives a so-called acid polish. The ware is coated with paraffine except in the cuts where the acid must act. The only medium that will eat glass is hydrofluoric acid. This is mixed with a certain quantity of sulphuric acid. The acid imparts sharp well fined lines to the cuts. The cuts are then buffed on Mexican felt wheels with No. FFF pumice powder and water. Such wheels are about 18 inches in diameter and are operated at 1200 revolutions a minute. A buffing operation with putty powder on a felt wheel usually follows. Circular depressions on cut glass ware are called *punties*. They are ground in place on artificial abrasive wheels generally.

Lens grinding is an important branch of abrasive work in

the glass trades. In general there are two kinds of surfaces to be ground and polished, cylindrical and spherical. In some instances it also is necessary to generate plane surfaces. A lens grinding machine is a simple affair consisting of a rotary lap mounted on the end of a vertical spindle. The lens blank, a piece of glass about $2\frac{1}{4}$ inches square is cemented to a cast iron holder with pitch. This holder has a depression on its upper side in which a pin projecting from a hand lever fits. Thus by moving the lever back and forth the lens is carried over the lap. Convex laps generate concave lenses and vice versa. The laps are cast iron, while the abrasives used are carbide of silicon and aluminum oxide. They are mixed with water. A box surrounds the lens-grinding tool in which the abrasive and water is mixed. Thus the abrasive thrown off by centrifugal force is caught and retained. First, roughing is done with grits ranging from 60 to 90. Then the lens and its block are cleaned very carefully and taken to another machine where 180 to 220 grit material is used. In some cases another operation with still finer material that has been used over and over again is used. Polishing is performed with rouge applied to a piece of broadcloth cemented over the grinding lap. Where large numbers of lenses of a like curvature are to be ground, a number of blanks are cemented on a curved block so that all the lenses can be ground simultaneously. Such an operation is performed on a semiautomatic machine. Cylinder and toric lenses are ground on special machines which feed the glass blanks back and forth over special laps. The abrasives used are the same as employed for grinding spherical lenses.

The edges of lenses formerly were ground by hand on large Craighleith stones. Today, however, special edge-grinding machines are used. Such a machine mounts the lens on a holder while a cam generates the necessary curvature as the lens edge is rotated against a fine grit aluminum oxide wheel. For many years it has been customary to grind the edges of beveled lenses by hand, but lately a machine has been devised for this purpose also.

The tops of blown glass tumblers are ground in a special device which holds the work bringing it against an aluminum oxide wheel. This grinds away the *overblow*. Wheels for this

purpose are both ball and cone shape and are used either wet or dry as conditions dictate.

Glass stoppers in druggists' bottles, etc., are fitted by grinding them in place with fine grain aluminum oxide or carbide of silicon. The former often is preferred as it breaks down to just the right grade to perform effective, airtight work. In this operation the stopper is held in a special chuck and as it rotates, the bottle is held against it thus generating a ground seat between the two members.

GRANITE FINISHING

Machines used for polishing marble, granite and terrazzo surfaces, according to Nathan C. Harrison, are of three types, belt driven, electrically powered or air operated. The most popular polishing machines in use at the present time are the belt driven variety as such tools can be depended on to produce economically. For example, some of the more recent types of belt driven machines polish 40 square feet of stone at one setting. When polishing granite in the stone cutting yard, a number of blocks are placed together so that the upper surface is approximately level. A framework of boards is bound around the upper edge of the blocks extending upward about eight inches. All crevices are filled with a plaster of paris mixture to make an unbroken and practically waterproof surface. This structure is termed technically a *bed*. The first operation consists of *ironing*. It is performed with an iron scroll wheel mounted on the end of a vertical shaft. By means of a handle the wheel can be passed over any part of the stone surface. The abrasive medium usually is a metallic one called *shot*, and in some instances the operation is called *shotting*. This operation grinds the stone surface level. The shot is washed away with water and another wheel substituted. This device is termed an *emery* wheel taking its name from the time when emery was the abrasive used. The operation is sometimes termed *emerying*. The wheel is cast iron and the abrasive medium is carbide of silicon grain in grits from 60 to 80. A final operation is performed with putty powder with a felt wheel. This results in a high polish. Like methods and operations are followed when using pneumatic or electric machines, but with equipment of this kind the operations are carried out on a smaller scale.

HANDLE SANDING PRACTICE

Abrasives used for sanding handles are either quartz or garnet, the latter being preferred in the majority of instances. While garnet costs more than white quartz (which still is used extensively) the results are so much better that it now is generally being substituted, due to its superior cutting qualities and hardness.

All varieties of handles are sanded on sand belts which are made of heavy canvas, set up with abrasive and glue. Various kinds of handles include those for axes, picks, sledges, hammers, hatchets, hoes, etc. A nicely finished handle should be run over three belts. The first belt should be set up with No. 2 garnet or No. 3 quartz. This belt performs the roughing. The next belt should be set up with No. 1½ and the last belt with No. 0 material. Polishing is done on a canvas belt which instead of being set up with abrasive is waxed.

There are numerous recipes for this polishing wax. That most generally used for polishing the handles above mentioned is made up as follows: 125 pounds of resin, 15 pounds of paraffine, 3 gallons of demar varnish, 2 gallons of shellac, ¼ gallon of linseed oil. These materials are melted over a slow fire, or preferably in a steam kettle, care being taken not to heat the mixture too fast which would cause it to boil and become porous. While the mixture is melting, it should be stirred thoroughly. Then it is molded into sticks. Stiff cardboard tubes, such as mailing tubes, can be used. One end is closed and the material poured in. The stick of wax is applied to the belt while it is running.

In setting up sand belts with abrasive the following method can be used: First, in order to secure a good foundation, a preliminary coat of very hot glue should be applied to the belt. It is a good plan to put the belt on the strapping machine during this operation so that it can be stretched tightly. The glue is applied and allowed to dry under tension. This can be done just before the close of the day's work so that the belt will be ready to set up the next morning.

After the preliminary coating of glue is dry, a second coat of thick glue is applied. Then the belt is turned over on the abrasive, which should be spread ½-inch deep in a trough. Then the belt is pounded well into the abrasive with a flat-end

pestle. In setting up a belt 15 feet or less in length, apply the glue to one-half the length and put on the abrasive—then set up the other half. For belts of greater length than 15 feet, apply the glue to only a short length at a time. This will prevent the glue setting before the abrasive is applied and it will insure a smooth cutting surface.

An hour or so after the foregoing operation has been completed, apply a coat of glue about 40 per cent of the former strength to the face of the belt, over the abrasive. If this coat of glue is too thin it will not hold the abrasive—if too thick it will cause the belt to glaze. No difficulty should be experienced in making up this glue after the second trial. When put on properly the result will be a saving of 25 per cent of the abrasive so that the life of the belt is increased materially.

When the abrasive wears off or fails to cut, repeat the last two operations. The number of times this may be done depends on the care exercised and the grade of work to be finished. When it is found that the surface of the belt is getting rough and has holes that do not fill with the glue and abrasive, drop the belt in a pail of warm water and after an hour scrape it clean of glue, using the back of an old knife or any blunt instrument that will not cut the fibers. This is the work of a very few minutes, after which the belt is as good as new, so that the operation of setting up can be started over again. Under ordinary circumstances, a belt can be re-set from six to ten times before it requires cleaning off. A strong flexible glue is necessary for the successful setting up of the belts in question. The foregoing data were supplied by the Klotz Machine Co.

HORN GRINDING

Horn is a comparative easy material to grind if the proper wheel is used. In general carbide of silicon is preferred. The work is done by hand in most instances, that is, it is held against the wheel without the aid of a fixture. In some cases, however, fixtures are employed. For example, in grinding horn stems for tobacco pipes before they are bent the work is held between centers in a fixture and pressed against the wheel. The work then is rotated, a cam giving the proper contour to the ground surface.

LAPPING PRACTICE

Lapping operations are of two kinds, plane and cylindrical. The former method is many centuries old and it takes its name from *lapidary* which today refers to the cutting of precious stones. Lap is a contraction of this word. The abrasives used for lapping are emery, corundum, aluminum oxide and carbide of silicon. The latter is more particularly adapted for lap-cast iron. These abrasives are used in flour form for fine lapping and in fine grain form for other purposes. Emery is slow cutting, but it imparts the highest finish of any known abrasive. Corundum cuts fast and leaves a good finish. This also is true of aluminum oxide. Carbide of silicon cuts very fast. The abrasive must be clean and kept in a container to exclude dust, for a small amount of foreign material will leave scratches that will ruin an otherwise good job. It is an excellent plan to purchase the washed material, such as is used for grinding lenses.

Laps used for plane lapping are tin or cast iron. The former holds the charge of abrasive well, but the latter often is preferred because it is more durable. In lapping hardened steel surfaces, such as gages and other small parts, the lap can be used dry or lubricated with oil, preferably olive oil. The oil should be rubbed on the lap by hand. Then a small quantity of abrasive should be sprinkled on. Here is where many make a mistake, for by applying too much abrasive the work cannot be lapped flat. This is because the material *banks up* under the edges of the work where it performs the major part of the cutting. The amount to leave for lapping should be slight, just enough to remove grinding wheel marks. Approximately 0.00025-inch is sufficient to remove the marks left by a 46-grit wheel. The size of the piece, of course, is another factor to consider. For example, the larger the piece the more it is liable to warp, even in the grinding operation, so that in general the larger the surface to finish, the more liberal the allowance must be. At best, hand lapping is a slow process. If care is exercised an ordinary mechanic can lap work such as hardened size blocks within 0.00005-inch if he is provided with standards with which to check his work. Before testing the work with gages or micrometers it should be washed in gasoline to remove the abrasive and the oil.

Many parts can be lapped within a close degree of accuracy on a fine-grit, aluminum-oxide, sharpening stone. In this case the stone must be true and lubricated with gasoline only. This method, of course, is not practicable for finishing gage surfaces, but for an operation such as finishing the tops of slip bushings for jigs so that the sizes will show plainly, the method is rapid and efficient.

Hand lapping of such parts as the jaws of snap gages can be accomplished by the method shown in Fig. 1. In this case the lap is a small cast iron piece held in a vise. The

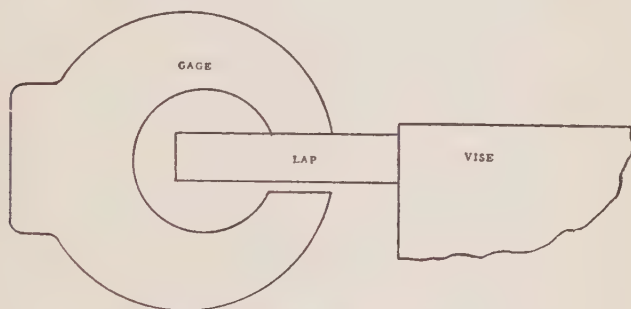


FIG. 1—LAPPING A SNAP GAGE BY HAND

gage is moved over the lap by hand. This is an exacting operation and it never should be relied upon to remove more than the very slight amount necessary to take out wheel marks. Gages can be lapped by another type of lap which is described further on.

Horizontal cast iron rotary laps can be used to advantage for finishing a large number of parts of a precision and semi-precision nature. In this case the lap is rotated at a surface speed of approximately 15 to 20 feet per minute. The abrasive is fine grit material, depending on the nature of the work. Thus for lapping such parts as the under sides of gear covers for machine tools, etc., No. 90 carbide of silicon could be used. For lapping steel parts to a high degree of finish flour abrasive would give good results. It is doubtful if the rotary lap used with grain abrasive for finishing cast iron surfaces is more economical than the disk grinding machine. However, these laps are used to some extent by machine tool builders for the foregoing purpose and in fact for finishing any flat surface

on a comparatively fragile part that cannot be located to advantage for planing or milling.

Vertically operated precision laps are used for a diversity of purposes, principally for lapping such work as snap gages. Such a tool is shown in Fig. 2. It consists of a cast iron center, *A*, and a lead and tin composition rim, *B*, the proportions of lead

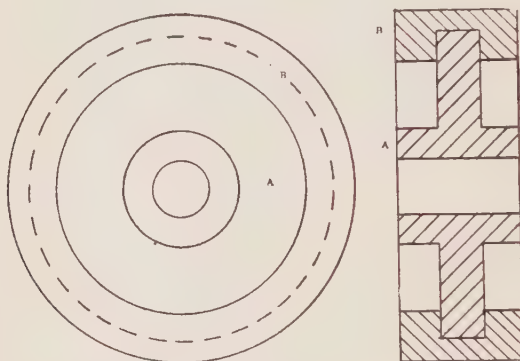


FIG. 2—VERTICALLY OPERATED LAP FOR PRECISION WORK

and tin being about equal. Babbitt metal sometimes is substituted for the foregoing mixture.

Laps of this kind can be used on a small universal grinder or on a profile grinder. If the former type of machine is used it is necessary that the platen cross travel is aligned carefully with the wheel spindle axis so that they stand at right angles. A rotary lap must run true to accomplish the best results. It is necessary to true the lap carefully each time it is mounted on the wheel spindle. A simple truing method is shown in Fig. 3. The lap is turned off on both sides with the tool shown strapped to the machine platen.

The next step consists of charging the lap. This is accomplished by rolling the abrasive in place with a small metal roller as shown in Fig. 4. The purpose of the roller is to force the grains of abrasive material into the soft metal lap. The fineness of abrasive depends on the character of the work. In actuality, however, the grains protrude from the lap so that a cutting action is set up. The abrasive can be rolled in dry or with oil. The latter method is preferable. In using the lap the work is strapped to the platen and fed back and forth,

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the depth of cut being controlled by the platen longitudinal feed screw. As both surfaces are lapped at one setting, it is obvious that they should be parallel. The lap should be a little

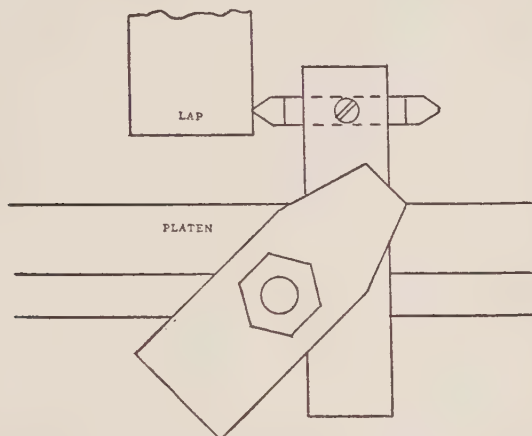


FIG. 3—TRUING A LAP WITH A TURNING TOOL

less in width than the opening in the work so that it cuts on one side at a time only. The lap should be lubricated with oil during the operation and it should not be rotated faster than 20 surface feet per minute. If it is run faster the abrasive does not have a chance to cut properly and again the work will be overheated.

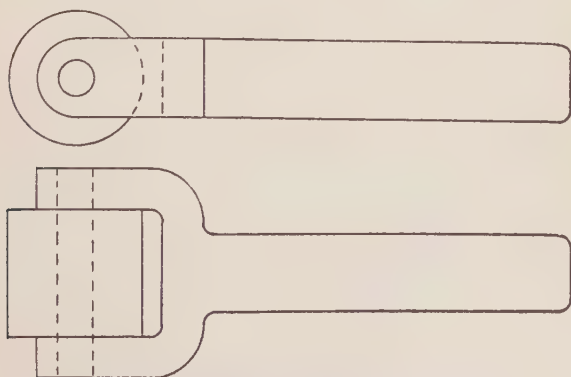


FIG. 4—ROLLER FOR CHARGING A LAP

Cylindrical lapping is of two kinds, external and internal. A lap for external work is shown in Fig. 5. It is made of cast iron and equipped with a screw at the split end for closing it. It is fed back and forth over the piece to be lapped while the latter is rotated slowly. Fine abrasive powder and oil is used. This type of lap possesses one advantage in that it



FIG. 5—SIMPLE LAP FOR EXTERNAL WORK

charges itself. External cylindrical lapping is not a difficult procedure, although of course care must be exercised in applying the abrasive and not running the work fast enough to cause undue heating.

A makeshift method sometimes followed in external cylindrical lapping is to apply abrasive and oil by means of a soft wood stick held against the rotating work. The best that can be said of this practice is that it is not practical and that it does not produce accurate results. One might as well per-

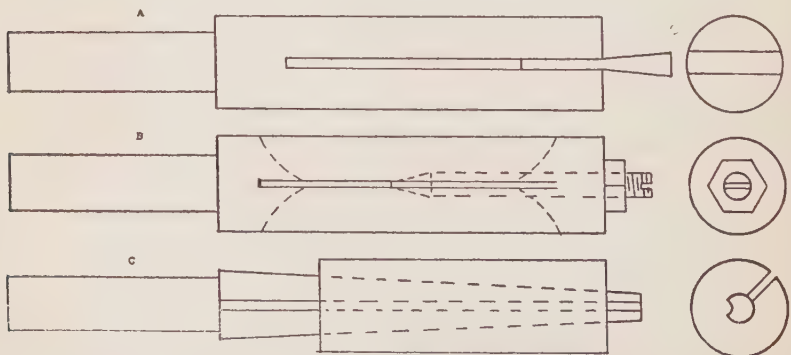


FIG. 6—THREE TYPES OF LAPS FOR INTERNAL WORK

form lapping with emery cloth, which would give just as good results.

Internal lapping is a precision operation in which care must be exercised to produce creditable work. Three forms of internal laps are shown in Fig. 6. The one illustrated at *A* is made of copper or brass and split for the accommodation of a wedge at the end which expands it. A better design is shown at *B*. This is a cast-iron lap split in four places and expanded by a taper end screw. At *C* is shown a lead lap molded over a taper spindle fitted with a groove to prevent the lap turning. This lap is split so that it can be driven up on the arbor and thus expanded.

In using such laps, the amount to leave for lapping depends on the condition of the work. When lapping jig bushings that have not been ground from 0.005 to 0.025-inch, depending on the size of the hole, must be allowed. In general, all holes over $\frac{3}{4}$ -inch should be ground before lapping. Sometimes, however, this is not possible. In lapping delicate, accurate work, such

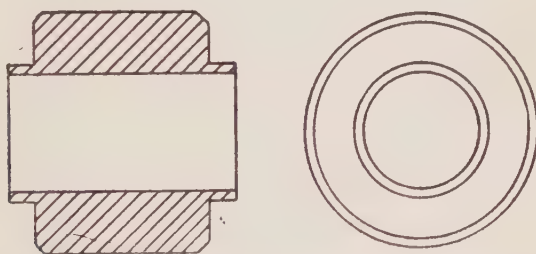


FIG. 7—PROJECTING ENDS ELIMINATE BELL MOUTH

as ring gages care must be exercised to prevent the work being bell mouthed, which is caused by the grains of the abrasive collecting at the ends. Careful toolmakers often overcome the difficulty by making ring gages with projecting ends as shown in Fig. 7. After the gage is lapped to size the projections are ground away.

Many parts are lapped on a production basis with a high degree of accuracy. This is especially true of size blocks which are made in large quantities by those specializing in their

manufacture. At one time it was thought that the Swedish gages were the most accurate to be produced, but at the present time American manufacturers are marketing an equally accurate product. The secret of the high degree of accuracy attained lies in the heat treatment of the steel and the lapping process. Such work is lapped between flat plates that are very carefully made and frequently repaired. Special machinery of the highest order is employed. For example, the Pratt & Whitney Co. control a number of patients on this equipment. These precision lapping machines embody two circular plates between which the work is interposed. Usually it is necessary to provide special holding fixtures. Lapping machines also are used extensively for finishing cylindrical work such as automobile-engine piston pins. In this case the work is located on a spider fitted with a number of arms, the spider and the work being located between the lapping plates.

The following data pertaining to precision cylindrical lapping was furnished by C. T. Appleton: The method consists of placing a number of piston pins loosely on a quick-loading work spider which is located between two lapping wheels. Both wheels rotate in opposite directions at a slightly different speed. When lapping, the upper wheel is brought down on to the piston pins under pressure, and the variations in work supplied cause the pins to rotate between the lapping wheels and creep slowly in a circular path in the direction of the faster wheel. The projecting arms on the work spider are not radial with the center of the spider, thereby causing the piston pins when rotating to have a rotating sliding action between the wheels.

The center of the spider rotates eccentrically with the center of rotation of the wheels, thus giving three distinct actions of the work in the wheel, as follows:

- 1—The creeping of the work caused by the variation in wheel speeds.

- 2—The sliding rotating action caused by the work being set on an angle instead of being radial to the center of the wheels.

- 3—The eccentric spider motion giving an in-and-out sliding action of the pins from the center of the wheel.

For production purposes, at least two machines are regu-

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larly used, one for rough and one for finish lapping. This method is economical and satisfactory. However, where a small production will not warrant the use of two machines, one machine may be used by being equipped with a pair of roughing and a pair of finishing wheels, both complete with flanges. Where two machines are used, that is, one for roughing and one for finishing, a spider full of pins is placed in the rough-lapping machine, and when inspected satisfactorily, the spider with the pins is passed directly to the finishing machine. This condition permits the pins lapped to exactly the same diameter to be passed on to a finishing machine without removing them from the spider. In the case of the small production where only one machine is used, it is, of course, necessary to first rough-lap a quantity of work and then set the machine up for finish lapping. To obtain the maximum results on a high-production basis a number of work holders are used, thereby permitting extra holders to be loaded while the others are in use on machines.

Piston pins are made in various ways, a typical method of which might be outlined as follows:

Material: Cold-drawn steel, S. A. E. 1020, 2315, 3120; stock is purchased 0.015 inch over finished pin size.

	Stock removed, inch	Stock left for next operation, inch
<i>First Operation:</i> Machine hole and ends complete in automatic scraw machine.....	0.0000	0.0150
<i>Second Operation:</i> Heat-treat. Fill central hole with asbestos and carbonize $\frac{1}{2}$ inch to $\frac{1}{8}$ inch deep (average $\frac{3}{8}$ inch). Harden to scleroscope hardness 80 to 85.....	0.0000	0.0150
<i>Third Operation:</i> Rough-grind in centerless grinder with three cuts:		
First cut, stock removed.....	0.0050	
Second cut, stock removed.....	0.0050	
Third cut, stock removed.....	0.0025	0.0025
<i>Fourth Operation:</i> Finish-grind in centerless grinder with two cuts:		
First cut, stock removed.....	0.0015	
Second cut, stock removed.....	0.0005	0.0005
<i>Fifth Operation:</i> Rough-lap in cylindrical lapping machine	0.0004	0.0001
<i>Sixth Operation:</i> Finish-(polish) lap in cylindrical lapping machine.....	0.0001	0.0000

TOLERANCES

The limits usually allowed on the finish-lapped piece are as follows:

Roundness	within 0.0001 inch
Taper	within 0.0002 inch
Diameter	from 0.0002 to 0.0005 inch

The out-of-roundness of the work produced on the machine is negligible, as this is practically zero in every instance. The diameter and the taper can easily be kept within 0.0002 inch without any unnecessary effort on the part of the operator. When necessary, the diameter can be kept within 0.0001 inch with special care on the part of the operator. It is the standard practice to allow from 0.0004 to 0.0005 inch stock to be removed from the diameter in the rough lapping, and not more than 0.0001 inch in the finish operation.

Prior to the lapping operation the pieces are finish-ground with a fairly good finish, and it is the usual practice to leave the finish-grinding diameter oversize by the amount of stock removed in rough lapping, plus the tolerance obtainable in grinding. For example, if a piece of work were to be finish-lapped to 1.0000 inches minus 0.0000 inch plus 0.0002 inch, the analysis of the size for rough lapping would be made as follows:

Maximum diameter after finish lapping, inches.....	1.0002
Amount of stock to be removed, rough lapping, inches.....	0.0004
Minimum grinding diameter, inches.....	1.0006

Therefore, with the finish-grinding allowance of 0.0002 inch, the finish-grinding sizes range from 1.0006 inches to 1.0008 inches, thus necessitating the removal of 0.0004 inch to 0.0006 inch in the lapping. By removing this the piece after being rough-lapped would be to the high limit of the finish lap; therefore, the stock being removed from 0.00005 inch to 0.0001 inch in the finish lap would be within the finish tolerances.

Practically, the lapping time required in production is about the same for the roughing and finishing operations. To illustrate the rapidity in which the method produces lapped piston pins, the following data are given:

MISCELLANEOUS ABRASIVE OPERATIONS

Diameter of work, inches	Maximum length of work, inches				
	1	2	3	4	5
$\frac{3}{8}$	1340	1226	1095	980	862
$\frac{1}{2}$	1155	1050	950	847	730
$\frac{5}{8}$	1010	920	823	730	643
$\frac{3}{4}$	890	818	730	657	569
$\frac{7}{8}$	.....	730	657	585	512
1	.....	672	598	540	467
$1\frac{1}{8}$	.....	614	556	496	423
$1\frac{1}{4}$	.....	569	512	453	395
$1\frac{3}{8}$	.....	526	467	424	365
$1\frac{1}{2}$	.....	496	438	394	351
$1\frac{3}{4}$	.....	.....	395	336	307
2	.....	.....	351	307	278

Two machines generally are used, one for rough and the other for finish lapping. For rough lapping, a medium-grain, soft grade of emery wheel is used, while for the finish lapping the very finest possible grain and softest grade of wheel is used. The lower wheel is rigidly mounted to the lower-wheel spindle, while the upper wheel has a floating action on the upper-wheel spindle. This floating action permits the upper wheel to find itself perfectly parallel with the work and cutting surface of the lower wheel. When truing either wheel, it is, of course, necessary that both wheels be rigid. The upper-wheel clamping flang mounted on the spindle has therefore been arranged with three square-head set-screws which, when screwed downward, remove all the floating action in the upper wheel. Therefore, to true the upper wheel, this wheel is raised and locked so that the cutting surface is on a plane just above the upper diamond mounted in an arm on the left side of the machine.

The truing arm is arranged with two independently operated diamonds, one for the upper wheel and one for the lower. With the truing arm in position, the upper diamond is adjusted upward by a knurled collar until it just comes in contact with the upper wheel. The diamond is then fed back and forth across the wheel by the use of the truing-arm hand-wheel located adjacent to the arm.

The lower wheel is trued in an identical manner, and in order to keep the wear of the wheels at a minimum, as light a cut as possible is removed by the diamond. Under average conditions it is only necessary to true the wheels about every 3000 to 5000 pins. It is of advantage occasionally to dress the wheels, thus eliminating the necessity of truing. This is done by simply passing a dresser back and forth over the cutting surface by hand. As the wheels are thoroughly moistened by

the constant flow of compound, the diamond produces a wet chip, and thus prevents emery dust from flying on to the machine. After truing, the wheels are washed and thoroughly cleaned from all loose emery, thus permitting all grains to be cleanly open and preventing any of the emery from getting on the work.

It has been found most satisfactory to date to use a grinding compound when lapping. This solution keeps the wheels and work clean at all times, and also prevents rusting. It may be said that this process of lapping is absolutely clean from emery, which eliminates any possibility of emery getting into the bearings in which the finished lapped parts are used. In making a careful study of the subject, the varying factors so far presented are as follows:

- 1—Amount of stock removed
- 2—Work
- 3—Eccentricity of work spider
- 4—Speed of wheels
- 5—Dressing of wheel cutting surface
- 6—Truing of wheel cutting surface
- 7—Cutting compound
- 8—Pressure of wheels on work
- 9—Number of pieces on work spider
- 10—Number of pieces lapped
- 11—Grade and grain of wheel
- 12—Time

To obtain the most important variables and eliminate the constants, each may be taken separately in the order previously listed.

1—*Amount of Stock Removed.* The amount of stock removed in the rough lapping is controlled by the limits obtainable from the finish centerless-grinder operation and the tolerance allowed on rough lapping. From the practice previously referred to, the variation in stock removed in the rough lapping is from 0.0004 to 0.0006 inch. As it has seemed most practical to perform a test on a manufacturing basis, the variable of 0.0002 inch has been disregarded, so that the amount of stock removed may be considered as a constant.

2—*Work.* Due to the large number of one type of piston pins being manufactured when the test and experiments were

MISCELLANEOUS ABRASIVE OPERATIONS

made it was possible to proceed to make the entire test on one type of pin, thereby keeping all dimensions, material, and hardness of work constant.

3—*Eccentricity of Spider.* This condition can be varied, and it was therefore necessary to find the effect on the work caused by the changing of the eccentricity of the spider.

4—*Speed of Wheels.* To determine the exact action of the grade and grain of the wheel on the work, it is necessary to find out the effect on the work caused by the varying of the speed of the wheels.

5—*Dressing of Wheel Cutting Surface.* For the present tests are based on one dressing of the wheels per experiment, although at a later date it may probably seem to advantage to find the effect of the rate of production and the finish of the work caused by the dressing of the wheels.

6—*Truing of Wheel Cutting Surface.* Also, in the case of truing, for the present it seems advantageous to true the wheels only once per experiment.

7—*Cutting Compound.* For experimenting, the volume of cutting compound was kept constant, with a flow of 10 gallons per minute, the ingredients of the compound being in the ratio of 1 pound of material to 10 gallons of water.

8—*Pressure of Wheel on Work.* It is self-evident that varying pressures of wheels on the work would affect both the rate of production and the finish. It is therefore necessary to determine this by considering pressure as a variable.

9—*Number of Pieces on the Work Spider.* So that the pressure of the wheels per square inch of work surface is kept constant, the same number of pieces on the work spider is necessary for all experiments.

10—*Number of Pieces Lapped.* To obtain accurate results it is absolutely essential that the total number of pieces lapped per experiment be kept constant. It is therefore decided to make each experiment consist of 1500 pieces.

11—*Grade and Grain of Wheel.* The cutting action furnished by the wheel depends considerably on its grade and grain. It is therefore obvious that different wheels will have to be used.

12—*Time.* Time may be considered a rate of production. All other conditions in this test are affected by the time element, and it is believed that all results obtained will be most satisfac-

tory when based relative to time. The time element in all conditions is therefore considered as a variable.

Summary—From the previous paragraphs the constant and variable factors can be summarized as follows:

Constant:

- 1—Amount of stock removed
- 2—Work
- 5—Dressing of wheel cutting surface
- 6—Truing of wheel cutting surface
- 7—Cutting compound
- 9—Number of pieces on work spider
- 10—Number of pieces lapped

Variable:

- 3—Eccentricity of work spider
- 4—Speed of wheels
- 8—Pressure of wheels on work
- 11—Grade and grain of wheel
- 12—Time

DIAMOND LAPS

Diamond laps are used extensively for lapping small holes that cannot be ground. They are soft steel charged with diamond dust which is rolled in place. The lap is laid on a small cast-iron plate, some diamond dust sprinkled on and another plate laid on top of the lap. By exerting pressure while the upper plate is moved back and forth the diamond dust is rolled in place. Diamond laps generally are run at high speeds, about 1500 feet per minute surface speed on an average. Face-plate laps charged with diamond dust also are used to a considerable extent. As such laps are expensive to maintain, substitutes are used whenever possible.

CRANKSHAFT LAPPING

Crankshaft lapping is an important operation performed to remove the minute marks left by the grinding wheel. In some instances it is performed with fine grit emery or manufactured corundum cloth held in polishing clamps. Again, lead laps charged with emery and oil are used. The work is held between set centers and rotated about 100 revolutions per minute. Thus in lapping the crankpins the lap and its handle will have a

movement like a connecting rod. Usually it rests against the bed of the speed lathe employed to locate and rotate the shaft. Crankshaft buffing machines are a recent development to take the place of the more or less expensive hand lapping. While the operation is a buffing one in the strictest sense of the word, it takes the place of a lapping operation. The present-day crankshaft honing machine, however, which is strictly a precision tool, is rapidly gaining favor as a crankshaft finishing unit.

LEATHER WORKING

Abrasives are used extensively in leather working. The suede leather of commerce is nothing more or less than ordinary sheepskin that has been ground on a carbide of silicon barrel-shaped wheel provided for this purpose. Such a wheel is called a *wet wheel* and the process is called *wet wheeling*. Such wheels are 60 grit, 16 inches in diameter at the center tapering to 13 inches at the ends. They are 18 inches long and are operated at 850 revolutions per minute. They are cleaned occasionally with a hot sal-soda solution. These wheels cut remarkably fast. In wet wheeling, the flesh sides of lamb skins for making ladies' long gloves one operator can perform the first operation, cutting down, on 10 dozen skins per day. On the second operation he can do from 20 to 24 dozen skins per day. In making suede leather a good operator can do 24 dozen skins a day.

In sharpening the knives of leather shaving machines, the wheel is made to run automatically back and forth past the circular knife that shaves the leather. This keeps the knife in good condition. Such wheels are about 9 inches in diameter, 1-inch face, 70 grit, aluminum oxide. One wheel will last 60 days, in shaving from 200 to 250 skins a day. For the band knives on leather splitting machines are sharpened continuously by an aluminum oxide wheel that runs against them. This wheel is 10 inches in diameter, 1½-inch face, 30 grit. Such a wheel lasts from six weeks to two months. For sharpening the knives of fleshing machines, aluminum oxide bricks are used extensively. These are about 8 x 3 x 2 inches in 30 grit. Carbide of silicon bricks sometimes are used for this purpose also. This sharpening is not done automatically but on occasion as the knife gets dull. It is performed by feeding the brick past

the revolving knife by hand over ways provided for the purpose.

The operation of *bucktail* leather consists of smoothing down rough spots on skins that have not been buffed, in buffing over scars and other defects and in buffing hard spots. It is performed on a wood wheel setup with No. 90 carbide of silicon grain. These wheels are of all sizes, some being 12 feet long and three feet in diameter.

Leather buffing consists of going over the grain side of skins with a wheel covered with carbide of silicon paper from 120 to 220 grit. The wheels are wood of various sizes and shapes. Considerable skill is required in the operation. In some instances the skin is fed over the wheel by hand and in other cases a sort of press roll is provided to enable the operator to hold the work against the wheel.

Abrasives are used extensively in shoe shops on a number of important operations. Tap scouring consists of grinding down leather shoe taps by feeding them through a machine not unlike a single drum sander. This machine carries a roll covered with garnet or carbide of silicon paper. Such machine usually is connected with an exhaust system for carrying away the dust. The material often used is 30 grit combination paper and cloth and a sheet $9\frac{1}{4}$ x 15 inches has been known to scour 3000 taps.

The different operations on shoes vary in different shops but in a representative factory they are divided as follows: Fore part buffing (sometimes called fore part finishing), heel scouring, top lift scouring, shanking out and heel breasting. Fore part buffing is done with carbide of silicon paper on the front or sole of the shoe. Two grits of paper are used, 150 and 180 grits, respectively, for the rough and finishing operations. In one factory one sheet of paper, 12 x 12 inches, 150 grit, roughed 48 pairs of men's shoes. In the finishing operation a higher production is possible. Heel scouring consists of finishing the sides of shoe heels. It is done with carbide of silicon paper stretched over a felt covered wheel. A strip of 50 grit paper will finish 72 pairs of men's shoes. Top lift scouring consists of finishing the top lift or last layer of leather on heels. It is done with 70 grit carbide of silicon paper mounted on a special wheel. One strip of paper will scour 72 pairs of men's

shoes. Shanking out consists of finishing the shoe shank, that is the part directly under the wearer's instep. It is performed on a special wheel called a shanking out wheel covered with No. 120 grit carbide of silicon paper. A strip of 120 grit paper will finish the shanks of 275 pairs of shoes. Shanking out pads also are used for this work. Some of them are mounted on pneumatic holders so that the work conforms to the abrasive readily. One pad will finish 48 pairs of shoes. Heel breasting consists of finishing the front of the heel. It is done with a carbide of silicon pad in 50 grit. One pad will do 400 pairs of shoes. Many years ago garnet was used exclusively for finishing shoes, but carbide of silicon has replaced the former abrasive almost entirely.

LEHR-BLOCK GRINDING

The bottoms of lehrs in which plate glass is annealed are fire-clay blocks. These require grinding occasionally to make them level. Fire clay can be worked readily with abrasive wheels and one of the methods followed in finishing these blocks is to grind them on a large planer-type grinder. It is best to take the block that is worn the greatest as a guide, finishing it first. Then the other blocks can be ground to the same thickness. A wheel for this work should be carbide of silicon about 16 grit and a medium hard grade. The grinding operation does not differ essentially from any other surface grinding job. Another method followed in finishing these blocks is to grind them on a rubbing bed as used for finishing stone. However, in this instance, the blocks must be sent away for grinding which institutes an additional delay. For this reason when lehr-block grinding is necessary it is general practice to use a home-made grinder rigged up by attaching a grinding head to the cross-slide saddle of an ordinary iron planer. The feed mechanism must be altered so that a cutting travel of from 15 to 20 feet per minute is had. This is accomplished readily on an ordinary planer by substituting a small drive pulley for the regular one on the line shaft. Means also must be provided for driving the grinding wheel at a peripheral travel of approximately 5000 feet per minute. As fire-clay grinding is a dusty job, it preferably is performed wet. Good results can be attained, however, by using an exhaust pipe to carry away the superfluous dust.

MARBLE FINISHING

Marble slabs, pilasters, stairway balusters, handrails, etc., are worked almost exclusively with abrasives. Marble slabs are cut up on a machine called a coping machine. It somewhat resembles an iron planer, being provided with a thin elastic wheel which is operated wet. Coping wheels often are furnished with a steel center. Marble sections are surfaced on a machine called a drum rubber. It also resembles a planer, but the wheel is a long, sectional cylinder, usually carbide of silicon. A hand-operated machine carrying a head equipped with a number of alumina abrasive hones is used for final surfacing in many instances. The hone head is located on the end of a vertical spindle, so arranged that it can be passed over any part of the work. These hones are fine grit artificial corundum, generally. Form grinding of such parts as hand rails for stairways is performed readily on the planer type machine with a wheel formed for the desired shape. Balusters are rotated and ground to shape on special lathes by means of form wheels also.

MARBLE FLOOR SURFACING

Surfacing machines of various types equipped with abrasive wheels or blocks are used extensively for finishing terrazzo, mosaic and marble floors, while abrasive rubbing bricks are employed by hand for working close to walls and in other places that cannot be reached readily by a surfacing machine, according to K. H. Lansing.

A terrazzo floor is composed of small chips of marble set in cement. The pieces may be of one or several colors, while different colored cements also are used in laying intricate designs. Such floors are quite durable. Mosaic work is a fine art handed down from remote times. It consists of fitting small pieces of variously colored materials together to form a design. As applied to modern floors, small pieces of different colored stones, usually marble, are employed. A marble floor is made of tiles, usually square, which are set on a cement bed. The tiles may be of one or various colors. One design embodies white and black squares set alternately to form a checker-board effect.

The first step in laying a terrazzo floor is to form a concrete bed. This bed is permitted to set for two or more days,

according to climatic conditions. The time necessary for it to set is determined wholly by experience. The next step consists of laying a so-called scratch coat which is composed of cement and fine, white sand. Some floor workers, however, do not consider this coat necessary. The pieces of marble are mixed with white cement, the quantity of the ingredients depending, of course, on the size of the floor to be made. The cement is mixed first and then the marble chips are added until the mixture is brought to the correct consistency. The mixture then is shoveled in place on the scratched coat and is allowed to set. As the floor sets, the marble pieces, being slightly heavier than the cement, settle to the bottom forming a closely bonded mass.

The next procedure consists of leveling the floor. This work is performed with a floor surfacing machine. Several types of these machines are in use, but they all embody a vertical shaft on the lower end of which a solid or sectional wheel is fitted. The vertical shaft is driven by an electric motor, the entire device being mounted on a track so that it can be moved over the floor readily. Means are provided for setting the wheel down to the work, while current is supplied by a cable connected to an electric circuit. When sectional wheels are used they are composed of blocks of various shapes which fit in a holder. Several abrasive wheel manufacturing companies supply these blocks. The principal abrasives used in making the blocks are carbide of silicon and aluminum oxide, while also natural stone hones are employed. The preliminary surfacing operation consists of wetting the floor and sprinkling it with white sand. Then the surfacing machine is brought into use. It is pushed over the floor slowly by hand while the abrasive wheel or blocks cuts away the upper surface of the cement until the pieces of marble are exposed. The operation is continued until the floor is level.

A thin cement coat next is spread over the floor, the object of which is to fill up any small holes. This operation is termed grading. After the floor is graded it usually is left until the building is finished so that the final finishing operation can be performed after the floor has been subjected to rough usage during building operations. The next operation, termed second gritting, consists of going over the floor care-

fully with the surfacing machine. This operation, of course, removes the final coat of cement leaving the floor smooth and level. Two more surfacing operations called third gritting and honing, respectively, are employed to bring the floor to the desired finish. The grits and grades supplied by the Carborundum Co. for this work are 40 grit, M grade, vitrified bond for the first roughing; 80 grit, M grade, vitrified bond for the second gritting; 150 grit, M grade, for the third gritting and FF grit, $\frac{1}{2}$ grade, for honing. Carborundum blocks are used for the first and second operation; carborundum aloxite for the third and fourth. The $\frac{1}{2}$ grade above mentioned refers to shellac bond. The hand rubbing bricks are of several grits running from 20 to 80. One type of brick is provided with angular slots on each side to facilitate the abrasive action.

In laying a mosaic floor the concrete bed is similar to that of a terrazzo floor. However, some operators prefer to lay an extra coat over the scratch coat, the mosaic pieces being pressed into the cement and held level by wood blocks and weights. Also in laying a mosaic floor it is the custom of some contractors to form the design by pasting the marble blocks to a stiff paper backing in strips from one to three feet wide. These strips are laid with the paper upward and, of course, the paper is removed as the finishing operation proceeds.

A tile floor is laid in practically the same manner, but these floors are not always surfaced. In some instances, however, they are leveled with a surfacing machine. Old floors that have been worn to some extent can be repaired readily by fitting in new sections where the most wear is apparent, after which the entire floor is resurfaced. Not all surfacing machines are designed to work close to walls so that hand blocks must be used to a considerable extent, especially on walls and columns. However, abrasive wheels carried on flexible shafts have been employed on this work to advantage.

NEEDLE MAKING

The material used in making of hand sewing needles at the plant of Milward & Sons, according to Joseph Horton, is steel wire of 0.85 to 1.1 per cent carbon content, depending on the class of goods for which it is required. It is produced from high-grade crucible steel rods at the company's wire mills at Sheffield. The various gages of wire are cut at the wire mill to

the lengths required, each wire being the length of two needles. They are sent in 7, 14 or 28 pound bundles to the Redditch mill. A typical bundle of "packet" for the production of size 8 sharp's needles, or the ordinary housewife's needle weighs 14 pounds and contains 72,000 wires, 0.024-inch diameter and $2\frac{7}{8}$ inches long, or sufficient to produce 144,000 needles $1\frac{7}{16}$ inches long.

From the commencement of manufacture, each packet of wires is accompanied by a work ticket, on which is recorded the names of all operators handling the wires or needles and also the waste and quantities sent forward at every process. By means of the records kept in connection with these tickets, any needle can be traced back to the billet of steel from which it came. The largest hand sewing needle in regular manufacture is 0.014-inch in diameter and 6 inches long, while the smallest is 0.006-inch in diameter and is used for stringing small seed pearls.

Before machining operations begin, the wires are placed in rings of suitable size, heated to an annealing temperature and rubbed with a flat face bar. This serves to straighten each wire by removing the slight curve left by the cutting machines, leaving the wires perfectly soft and straight. In this form, the wires are known as "stiffs."

The "stiffs" now pass to the first abrasive operation, pointing. The points are formed in a grinding machine of a standard type generally employed in wire pointing operations and extensively used by the makers of talking machine needles and the numerous varieties of steel points used in the textile industries. Formerly the wires were fed to the grinding wheels by hand, the operator sitting right over the stone. In those days, a pointer's life was a short one, due to the steel and abrasive dust which he inhaled as well as casualties due to bursting stones. To this day, a "pointers thirst" is a byword in the district. The operation is entirely freed from danger by efficient dust removal systems and the care taken by the manufacturer of abrasive wheels to test them thoroughly and to state the speeds at which they should be run. The grinding machines are fitted with efficient guards.

The wheels generally used are concave faced manufactured for the purpose. The face has a radius of 3 to 7 inches, accord-

ing to requirements and the wheels vary from 16 to 24 inches in diameter and from 8 to 4 inches face. The operation of pointing is semiautomatic, the wires being fed in a continuous stream across the face of the wheels and the operator only being required to prevent "jams" or "crosses."

A small wheel, or roll, faced with rubber meets the wires at right angles to the axis of the grinding wheel and in the concave face, carries the wires across, revolving each wire against a rubber-faced stationary saddle. Due to the axis of the roll being set slightly out of the right angle the wires first are ground at the extreme point. This operation "sets" the wire while the second stage grinds the long taper required. After one end of each wire has been ground, they are turned round and put through the machine again. Thus each wire is pointed on both ends.

The wheels require frequent dressing and considerable skill is required in setting up the machine. It has been found economical to have a skilled pointer to every machine except for the larger sizes of fish hook wires, knitting needles and crochet hooks. To keep the stiffes apart from each other and make them roll freely in passing through this machine and in later processes, they are frequently dusted with lycopodium, a powder produced from the fronds of ferns.

The mixture of abrasive and steel dust removed from the dust collecting plant is in great demand in the district for the construction of garden paths as when damp it settles into a solid form which appears indestructible. It cannot be used for roadmaking, unfortunately, as it contains a large quantity of steel points. These work through the material, however hard it sets, under the vibration set up by automobile traffic, with disastrous results to the tires.

The next operation which is also an abrasive one is termed "skimming" and consists of cleaning the oxide and scale from the surface of the steel about the middle of each wire. It is effected by passing the wires over a rapidly running emery band, the wires being traversed across the band by two revolving disks running on the same axis as the band but at a greatly reduced speed. The wires are revolved by passing along a fixed rubber-covered saddle.

The wires are now termed "points" and pass on to the "mak-

ing" processes. The production of the eye of the needle is effected in two operations by an ingenious tool. The first operation impresses the form of the two eyes on each point, or wire, and the second one punches out the blanks from the center of the eye impressions. The machine is automatic and produces about 7000 complete blanks or 14,000 needles per hour. The chief feature of the machine is the arrangement by which the needles are delivered to the tools in the exact position necessary for impressing the blank and punching out the eye by means of an air blast and air suction. After the wires are stamped and eyed, they are broken into single needles by hand, young girls taking up large handfuls and with a dextrous movement, dividing them between the eyes.

The needles, as they now are, pass to the next abrasive operation which removes the waste metal or "splash" thrown up around the sides of the eye by the stamping or impressing process. The same machine at a different setting, shapes the head above the eye. The needles are fed into grooves on the flanges of a wheel. The wheel revolves on to a tightly stretched rubber band which holds the needles in place and revolves them individually as they pass across the concave face of a small abrasive wheel about 3 inches in diameter.

The needles are now heat-treated and it is on the hardening and tempering processes that a large part of the reputation for quality enjoyed by English needles has been built. Great care is exercised to produce absolute uniformity and the latest types of furnaces and pyrometric methods are employed. Much waste (which is the bugbear of the needlemaker) can be made at these processes by lack of a little care or attention. It is interesting to note that the needles are not brought to the final temper in the tempering process, it being left to the polishing operation and the heat developed there to produce the temper for which needles are justly famous.

After heat-treatment, the needles undergo the scouring or polishing process which is the last abrasive operation. The present method of polishing needles has come down almost unchanged for 200 years and while frankly admitted to be clumsy and uneconomical, it has not been found possible either to substitute another system or improve the present one to give the quality of finish required; together with a sufficiently low per-

centage of waste. In passing it is of interest to note that it has been found through much experiment that no rust-proofing process, such as various methods or plating, are nearly so proof against rust and corrosion as a well scoured and finished needle by the old-fashioned method. The method of scouring is as follows: The needles are mixed with an abrasive consisting of emery powder, soft soap and water, they are tied up in bundles with canvas and cord, each bundle containing a "packet" of needles and resembling a large sausage about 18 inches long and 3 to 4 inches in diameter.

The scouring machines consist of heavy runners which are oscillated backward and forward over a solid table faced with steel. The needle packs are placed between the moving runner and the table and roll continuously for about a week. It is estimated that during this time, they travel a distance of some thirty miles. From time to time during the process, water has to be added to prevent the package running "dry," which would cause the needles to rust. Also the canvas and cord have to be renewed. The pressure or load on the runners is varied according to the size of the needles being polished. It is here that the heat is generated which produces the final temper. After leaving the scouring machines, the needles are thoroughly washed and dried in hot sawdust, the separation of the needles from the dust being carried out by a process probably derived from the old manner of winnowing grain.

The needle now is a finished article, but still it has to go through sorting, grading for length, and examination processes. Every needle is individually examined by skilled "viewers" for every one of the numerous defects to which it is liable. The speed and dexterity of the observers is wonderful. After the viewing process, the needles are stored until actually required for delivery to the customer, when they are counted out and packed into the various forms of paper and wrapper with which we are all familiar.

The abrasive operations in the manufacture of fish hooks, knitting needles and crochet hooks are not essentially different, the pointing of the highest grade of fish hooks however, not being a grinding process at all but being done by hand workers with a file.

It is interesting to note that the average production of

needles at the Milward plant is about 16,000,000 per week, that about 600 employes are engaged in needle making and preparing the papers and wrappers, of whom about 400 are women and girls.

PEARL GRINDING

Large quantities of pearl are made into novelties, handles, buttons, etc., the raw material being the shells of univalves and bivalves. Univalves generally are larger shells found in salt water, while fresh-water pearl is derived from clams found in the Mississippi river and its tributaries. Pearl is a difficult material to fabricate without abrasives and for this reason carbide of silicon wheels are used almost exclusively in the industry. The method followed in making pearl revolver handles is typical of that followed in making up any small pearl parts. The process is as follows:

After the pearl shells are sawed to size, they are ground on carbide of silicon wheels in 40 grit and a medium hard grade. In this operation the workman guides the material by hand so that considerable skill is required in the operation. However, templates often are used in getting the desired contours. The parts then are polished on leather wheels set up with No. 150 carbide of silicon grain. Next they are buffed on felt wheels with pumice as an abrasive. This leaves a smooth, dull finish. The luster is brought out by buffing on muslin wheels with rouge as an abrasive medium. The foregoing process is used in all varieties of pearl novelty work.

A number of abrasive processes are followed in the manufacture of pearl buttons. The blanks are cut from the shells by tube drills and then put through a backing machine which grinds the blanks all to one thickness. Next the front side of the button is turned. Then the back side is ground to the desired contour by holding it in a chuck and revolving it against a formed wheel. The holes are drilled and the final finish imparted by tumbling in special solutions such as pumice powder and water or weak acid.

Special machines also are employed for making buttons. Such machines are semiautomatic in motion and they perform several of the foregoing operations one after another.

PORCELAIN GRINDING

Porcelain syrup jars, trays, and slabs are used in multiples in soda fountain equipment and as it is essential that these parts be fitted closely together to make a neat appearance, it has been found that this can be attained very quickly by wet grinding on a double ring wheel grinding machine which grinds both sides simultaneously at one setting or chucking of the parts, according to Charles H. Besly & Co. In the manufacture of these parts, a slight offset is made in the top part of the jar or part where they are fitted together. This projection is made as narrow as possible to reduce the grinding area and increase production as also reducing the liability of breakage in the grinding operation.

The fixtures used for locating the work are grey iron and all parts coming in contact with the porcelain are lined with wood, secured to the castings with brass screws. Hard maple specially treated to withstand the soaking effect of cooling lubricant is used for the liners. They have a tendency to act as a cushion and reduce vibration as also keep the work from coming in contact with any metal part of the fixture which has become rusted and which would be transferred to the work and cause discoloration. Brass or bronze metal can be used in the fixture construction in place of the grey iron if desired but is not necessary when wood liners are used. Four fixtures were designed to take care of nine different parts, none of them being exactly alike. In some of the fixtures the work is held loosely in place which allows it to float between the grinding wheels. This reduces the strain on the work itself as also makes it possible to remove automatically about the same amount of stock from each side of the work.

Some pieces require to be rigidly chucked. This is accomplished without danger of cracking with treated wood-lined clamps and straps. This type of grinding equipment on the work in question is far more efficient in accuracy and production than the old time rubbing bed method which renders results in accordance with the method employed by the operator in holding the work in place. In many cases accuracy in size and right angles and parallelism are difficult to obtain on the rubbing bed, while with modern equipment it is merely a matter of placing the work in the machine.

RECURTING MILLING CUTTERS

The practice of generating new teeth in milling cutters without annealing them is not new and at the present time a number of concerns cater to this class of work. These shops are equipped with efficient tools for carrying out the work and, in some instances, the processes are guarded carefully so that they are not public knowledge.

However, ordinary milling cutters can be recut at a profit by any mechanic on an ordinary cutter grinding machine such as used for sharpening formed cutters. It must not be inferred, however, that this work can be done as economically in this way as it is prosecuted in a regular recutting shop. In Fig. 8 the view at the left is a section of a worn cutter with the preliminary recutting operation in progress, while the illustration at the right shows the second recutting step. The cutter is



FIG. 8—PROGRESSIVE STEPS IN RECURTING A MILLING CUTTER

mounted on an arbor and gashed out all around, as the illustration shows. The object of this procedure is to leave a place for the corner of the recutting wheel. The gashing operation is performed with an alumina abrasive wheel in elastic bond. The work is fed back and forth and a cut of about 0.002-inch in depth taken at each pass. Experience will teach the operator as to the correct depth of cut. After the cutter is gashed out all around it is recut with a wheel trued at an angle as the view at the right shows. The teeth are ground until the lands are about 0.01-inch wide. If the operation can be performed wet it will be more economical than if done dry. However, the average equipment suited for this work is not always arranged for wet grinding. If the cutters must be recut dry, care should be exercised not to make the cut deep enough to draw the temper.

The wheels should be about 46 grit in medium grades. No set rule can be given for their selection, but any grinding wheel manufacturer can supply them if he is given data pertaining to their use. In all instances they should be alumina abrasives.

At the plant of the King Tool Grinding Co. a battery of modern grinding machines is kept constantly busy on tool regrinding work. The process used eliminates the preliminary gashing operation. The first step in reclaiming cutters is to grind the peripheries. This is accomplished by mounting the cutter on an arbor which is placed between the centers of a cylindrical grinder. Sides of the cutter then are ground flat and true. The cutter is mounted on a rotary magnetic chuck while the wheel is fed back and forth over it. Just enough metal is removed to true up the sides. The wheel is manufactured alumina, 10 inches in diameter, $\frac{3}{4}$ -inch face, 60 grit, J grade, vitrified bond. It is operated at a surface speed of 5000 feet per minute, and the work is handled dry.

The next step consists of cutting the teeth. The principle is exactly the same as followed in ordinary cutter making, except that an abrasive wheel is the cutting agent instead of a milling cutter. For cutting the side teeth the cutter is mounted on a compound head set to generate the necessary angle while the wheel face also is beveled. The remarkable feature of this operation is the ability of the wheel to stand upon the corner; a no mean problem for the wheel manufacturer to solve. The teeth are ground one at a time, the cutter being positioned by a guide finder as in ordinary cutter sharpening practice.

In cutting the peripheral teeth, the work is mounted on an arbor which is placed between centers. After the side and peripheral teeth are cut, they are sharpened by backing them off to generate the necessary cutting angles. Spiral cutters are reclaimed as readily as straight ones. Milling saws are recut by placing several on an arbor at once. The recutting of reamers is performed by practically the same method followed with cutters.

SANDBLASTING PRACTICE

The sandblast process is not new as many suppose as the practice of abrading materials with an air or steam blast of sand has been in use for at least 50 years. It is said that

observations of the action of beach sand when violently blown on glass windows by storms gave the suggestion for the method. The first attempts at sandblasting consisted of imparting various intricate designs on glass. The material was covered with a stencil so that the sand acted only on exposed portions.

Latter day sandblasting is used in foundries for cleaning castings, in heat treating rooms for cleaning parts as they come from the quenching baths, for removing paint from metallic surfaces and for cleaning buildings. Various materials are used, such as silica sand flint quartz, a special material termed flint shot and chilled-iron metallic abrasives. The material to use depends on the nature of the work and experimentation only can serve as the best guide. In general it can be stated that ordinary sand is too soft. Quartz sand is harder, flint shot possesses many valuable characteristics and the metallic abrasives also are used extensively.

Various types of sandblast equipment are in use. The earliest form consisted of a sandblast chamber which was simply a room closed from the rest of the shop and equipped with a sand hose. Present-day sandblast rooms are equipped with efficient exhaust systems so that the air is changed constantly. Some are fitted with traveling conveyances that carry the materials to be cleaned through the room from side to side and in other cases with revolving tables or gratings that carry the castings slowly around in a circle. Thus the operator can perform his part by standing in one position. For cleaning large castings, an overhead trolley is provided for conveying purposes. Trucks and truck racks also are used and in some instances elevated platforms are provided on which the operator places the work. In cases where the operator must work in a sandblast chamber, he should wear a helmet equipped with an air line to provide him with pure air.

The revolving table outfit is a modification of the sandblast room. It is used chiefly for cleaning large castings that cannot be handled readily by other means. The castings are located on a revolving table which is from six to twelve feet in diameter. The rear half of the table is covered by a chamber fitted with sandblast nozzles. This chamber is separated from the outer room by slitted leather curtains. The castings pass under or through these curtains readily. As they enter

the chamber they are sandblasted automatically and on emerging again they are turned in position by the operator so that on the second trip through the cabinet surfaces are reached that were not hit by the blast on the first journey. The process of turning the castings is repeated several times until the entire surface of each one has been cleaned effectually. The waste sand and dust is carried down into a lower chamber then upward into a separator, the clean sand being returned for re-use.

The sandblast cabinet is a refinement of the sandblast room or chamber. These cabinets are constructed in a variety of ways and shapes, ranging from square wood boxes to cylindrical tank-like structures. In each case, however, the operation is the same, that of permitting the operator to have both hands inside the cabinet while he views the work from the outside through a glass window or a screened opening. In some cases the nozzle is stationary, the operator moving the piece under the sandblast. In other instances the sand nozzle is flexible so that the blast can be directed by the operator at will. Sandblast cabinets are used mainly for comparatively delicate work that is small enough to be handled readily. Automatic conveyors can be used to advantage in carrying the work through the cabinet.

Sandblast barrels are a modification of the old-time tumbling mill or rattler. The sandblast barrel revolves slowly so that the sandblast jet does the work instead of the erosion of the parts against each other. A sandblast barrel will do ten times the amount of work in a given time than can be cleaned in a rattler. Again, due to the slow speed of the barrel, delicate castings can be handled which would be broken by the rough usage in an ordinary tumbling barrel.

The open sandblast is used for a diversity of purposes, such as cleaning stone and brick buildings, cleaning castings, etc. The work is done in the open with the hose and nozzle connected with an air compressor and a sand supply. Sometimes sand is fed by gravity into a column of air under pressure. In other instances the sand and air are mixed under pressure. The tank can be portable or stationary. The sand gun is an appliance consisting of a hose and nozzle. One end of the hose sucks up the sand from a tank or hole while the

MISCELLANEOUS ABRASIVE OPERATIONS

other end is connected with the nozzle that is directed against the work.

A certain amount of waste accumulates in any sandblasting operation, as the process always creates a fine dust, while also the abrasive wear creates waste material. Means therefore are applied for retaining and separating the waste from the abrasive material so that it can be used over again. Two methods are employed: centrifugal separation and bolting. The former method is the simpler. In the bolting method wire screens or bolting cloth are used. The bolting element can be a long tube in which the descending dust is met with an

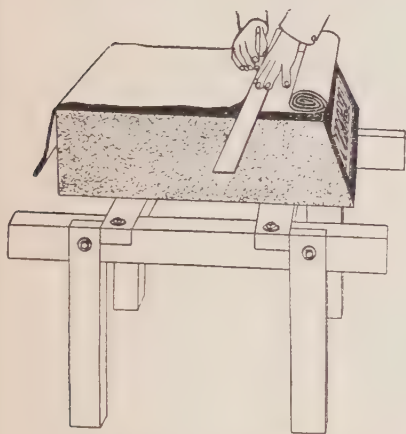


FIG. 9—THE DIE IS COVERED WITH A SPECIALLY PREPARED STENCIL OVERLAPPING ONE INCH ON ALL SIDES

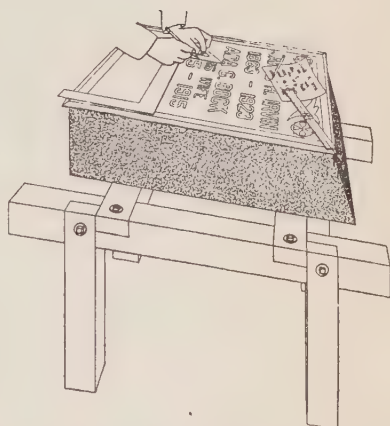


FIG. 10—THE DESIGN MUST BE LAID OUT CAREFULLY ON THE STENCIL FACE BY SKILLED WORKMEN

ascending column of air. The heavier particles fall to the bottom and the finer are blown out at the top into a receiver.

After separation, means must be provided for carrying away the dust without blowing it all over the premises. Such devices consist of overhead hoppers with tubular fabric spouts to convey the dust into closed receptacles. Another solution of the problem is found by moistening the dust with a water spray or steam jet which coagulates and precipitates it. The latter method has been used with excellent results.

A novel use for the sandblast process is the cutting of letters and designs on monuments. The process is comparatively simple and is said to be superior to lettering by

hand or with the aid of air chisels. The accompanying illustrations, which were supplied by the Pangborn Corp., show how the sandblast process is used in monumental yards. First the operator unrolls enough of a specially prepared stencil to cover the "die" as the stone face is called. The stencil, Fig. 9, must be wide enough to project about an inch all around the die. Then the stencil is wet with sponge and hot water until the composition on the stencil face is

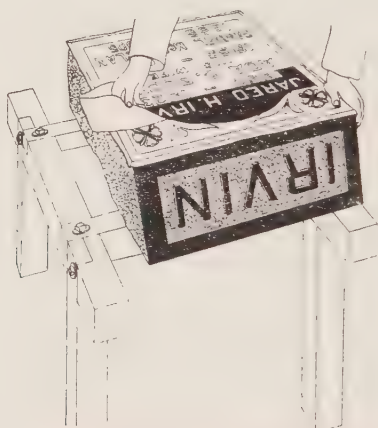


FIG. 12—THE PARTS OF THE STENCIL
OVER PORTIONS TO BE ACTED ON
BY THE SANDBLAST
ARE REMOVED

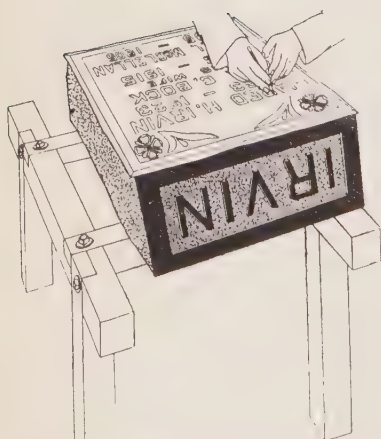


FIG. 11—THE DESIGN IS CUT AWAY
WITH A SHARP KNIFE FOLLOW-
ING THE OUTLINE JUST
DRAWN

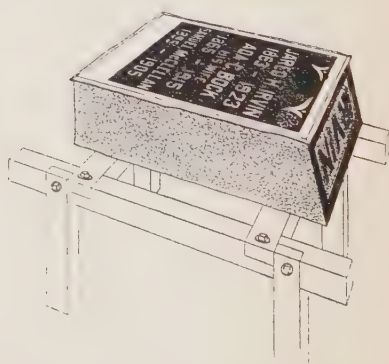


FIG. 13—THIS STONE IS READY TO
BE TAKEN TO THE SANDBLAST
ROOM FOR THE ABRASIVE
PROCESS

moistened sufficiently to cause it to adhere to the die face. Next the moistened side of the stencil is placed over the die and rolled in place with a hand roller provided for this purpose.

Considerable skill is required in the next step, which consists of laying out the design as shown in Fig. 10. Then the outline of the inscription is cut with a sharp knife as shown in Fig. 11. The stencil is stripped away as shown in Fig. 12, exposing the portions to be acted upon by the sandblast. For making raised letters the background is stripped off. When sunken letters are wanted the letters are stripped away. The stone shown in Fig. 13 is ready to convey to the sandblast room. The operator blasts the stone from the outside, looking in through a window to observe the process. The abrasive action set up can be judged from the fact that a nozzle lasts from two to three hours only when the blast is on continuously.

Both sand and metallic abrasives are used for sandblasting monuments. The sand is a dry, white silica product which has sharp cutting qualities. This material can be used many times, but it loses about 15 per cent of its volume in dust each time. Metallic abrasives cut very fast, require a minimum storage space and raise a small amount of dust only. In some instances sand and metallic abrasives are mixed; the theory being that the metallic abrasives cut fast and give a smooth surface, while the sand brings up a pleasing relief. One prominent user recommends 25 per cent metallic abrasive and 75 per cent sand.

SANITARY WARE GRINDING

Sanitary ware is a trade term for porcelain coated, cast iron sinks, bath tubs, wash basins, etc. The demand for such articles has increased enormously during the past decade. A number of abrasive operations are followed in finishing this ware. At the plant of the Union Sanitary Works, the first cleaning operation consists of sandblasting to remove loose sand, etc. Pronounced irregularities such as fins and sections where gates were broken off next are ground away under swing-frame grinders. The work is located on special trucks. For instance, a bath tub is set on a regular warehouse truck equipped with an extra long base. Portable electric grinders fitted with special wheels technically called *strawberries* from their shape are used to advantage for interior surfacing operations. The

backs of such pieces and sinks that must fit nicely against a wall are surface ground on a special machine wherein the work is fed past the face of a large cup or cylinder wheel. Surfaces that cannot be reached with wheels are scoured with abrasive bricks which are made of wheel stubs.

The object of grinding the various surfaces is twofold. First, exterior surfaces such as those on bath tubs must present a neat appearance and, again, all surfaces that are to be enameled must be clean and free of imperfections. After grinding the parts again are sandblasted to remove all traces of dirt and grease. Grinding is performed with carbide of silicon wheels.

The first finishing coat is a reddish brown pigment which is sprayed in place. Then the piece is transferred to an oil-fired furnace heated to 1700 degrees Fahr. Next it is withdrawn and a coat of powdered mineral composition sifted over the red-hot surface. This coat fuses and results in the beautiful finish for which these products are noted. With the second coat laid on carefully the piece again is transferred to the furnace for another heating. Sanitary ware will withstand the action of nearly all substances except certain acids. Lemon juice will ruin it.

TYPEWRITER-PLATEN GRINDING

Platens for typewriters are straight-grain poplar wood. The platen is located on its shaft between centers in a plain grinding machine and ground straight and true with a carbide of silicon wheel in 24 grit operated at a peripheral travel of 5000 feet per minute. This work, of course, is performed dry. Generally an exhaust system is fitted to the machine to carry away the dust. Usually the work rotates about 500 revolutions a minute. The depth of cut is about 0.05-inch. One operator can finish 175 platens an hour running two machines. After the rubber covers are put in place on the platens, the outer portion is ground smooth. This work is performed with the same wheel and in the same manner as followed in grinding the wood core. Two cuts are taken and the work speed is about 600 revolutions per minute.

UNIQUE GRINDING OPERATIONS

Francis D. Bowman states that grinding wheels are used regularly for a number of unique grinding operations. He points out that to step aside from the regular course of grinding practice and to wander through the by-paths brings the investigator to the realization that modern abrasives are an important factor in the industrial and commercial world.

Does the modern abrasive engineer realize that large wheels are used for grinding truffles? This statement may be taken for a joke, but it is authentic. Truffles are toothsome roots that are regarded as rare delicacies. They form an ingredient of certain delectable sauce concocted by the French chef and sometimes they are served with steaks and the dressings of roast fowls. They grow profusely in the region de Perigord in Southern France. They are underground roots of the mushroom family. Pigs are extremely partial to truffles, so the truffles gatherer enlists the porker's aid in a practical manner. The pig locates the truffle and digs it out. Then the truffle hunter raps the pig on the snout and takes the truffle away before it is eaten.

After the dirt is removed from the truffle it must be pared as it has a tough shell about $\frac{1}{4}$ -inch thick. It grieves the soul of the thrifty Frenchman to lose any of the edible weight of the truffle, so someone devised the plan of grinding away the thick skin. Thus the truffle grinding wheel became a commercial possibility. Records at the plant of the Carborundum Co. reveal that hundreds of wheels 30 inches in diameter, 4-inch face, 24 grit, H grade have been supplied for this purpose.

Grinding wheels also are used to a great extent in the feather industry for removing the fuzz of featherlets that grow along the quills of such feathers as ostrich plumes. Formerly the quills were clipped, but this process was slow and unsatisfactory so that grinding wheels were substituted successfully. Today grinding wheels are an important factor in the feather factory as their labor saving possibilities are realized.

For many years small grinding wheels have been used by dentists for grinding porcelain, that substance which forms the outer covering of teeth, but few users of abrasives are aware that grinding wheels are used regularly by veterinary

surgeons for repairing the teeth of horses. Formerly a file was employed for this purpose, the grinding plan originating in the British army about 15 years ago. The horse, being a highly nervous animal, objects to having his teeth filed, and now the operation is performed more rapidly and with less trouble with a small carborundum wheel mounted on a flexible shaft.

Another peculiar use for grinding wheels consists of finishing celluloid dolls. These toys are formed in molds, one-half at a time, and two sections are joined together. This leaves a seam that is removed effectively by grinding with carborundum wheels mounted on small bench stands.

Some years ago the Carborundum Co. received a request from Russia for sets of carborundum blocks. Investigation revealed that the blocks were used in a Moscow factory for making plush. The factory superintendent experimented with carborundum slabs 12 inches long, 2 inches wide and $\frac{1}{4}$ -inch thick, attached to long handles. The slabs were pushed across projecting fibers, the sharp crystals of carborundum raising a plush-like surface.

In the little village of Edar, in Southern Germany, agate, sapphire, turquoise and other semiprecious stones have been finished by grinding for many generations. The only change in the grinding method was made when artificial abrasive wheels were substituted for grindstones. The operators still lie on their stomachs while grinding. Huge logs, partly hollowed out and worn smooth through years of use, are placed one in front of each wheel, the operators lying face downward on these logs so that they can grind the work on the bottom of the wheels.

Grinding wheels also find a unique place in the whaling industry. The old practice was to cut the blubber in chunks, put it in huge cauldrons and boil out the oil. In the abrasive extraction process, a coarse carborundum wheel is used. This unit is 24 inches in diameter, 4 to 5-inch face. The chunks of blubber are held against the wheel, at the same time being heated with steam. The wheel cuts and shreds the blubber into a fine pulp which then is passed through a centrifugal separator. It is said that this process results in a high quality product that is odorless and tasteless, which extends its usefulness.

SECTION XIII

POLISHING AND BUFFING

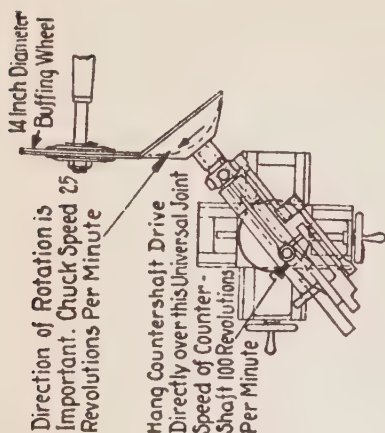
The data in this section were selected carefully as pertaining to up-to-date practice, but even at its best, polishing and buffing has not had the benefit of the study and research that have been applied to other branches of the abrasive industry. Some progress has been made during the past few years, however, and automatic polishing and buffing especially have passed the experimental stage and now are recognized as necessary where they can be employed on long runs of repetition work. The data in this section are arranged as follows:

	Page		Page
Automatic Buffing	473	Polishing Heater Parts	489
Automatic Polishing	475	Polishing Plumbers' Goods	490
Balancing Polishing Wheels	477	Polishing Radiator Shells	492
Binders for Buffing Compounds.....	480	Polishing Room Layout	493
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Grain Sizes for Polishing	482	Selecting Buffing Abrasives.....	504
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Polishing and Buffing Speeds	487	Strap Polisher	516
Polishing Cooking Utensils	487	Tallow Stick	516
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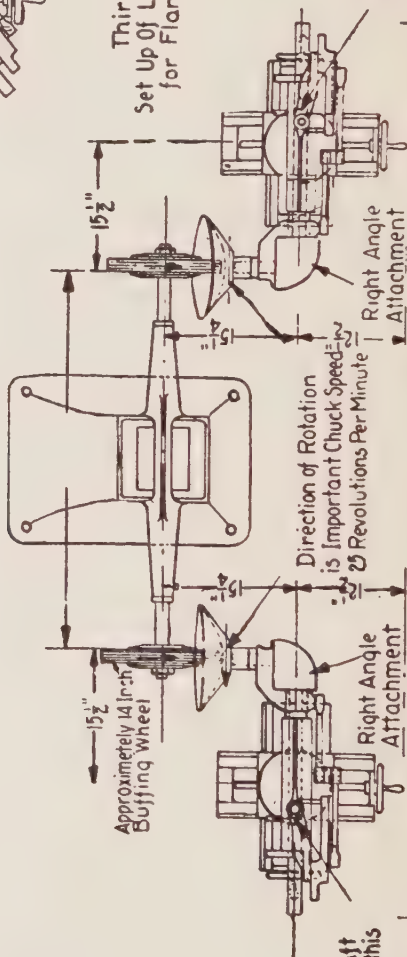
End View, Showing Position of Chuck for First Operation



End View, Showing Position of Chuck for Second Operation



Third Operation Set Up of Left Hand Machine for Flange on Reflector



Hang Countershaft Drive Directly over this Universal Joint. Speed of Countershaft 100 Revolutions Per Minute

First Operation Set Up of Left Hand Machine with Right Angle Attachment for Reflector

Second Operation Set Up of Right Hand Machine with Right Angle Attachment for Reflector

Hang Countershaft Drive Directly over this Universal Joint. Speed of Countershaft 100 Revolutions Per Minute

DETAILS OF LAYOUT FOR AUTOMATIC BUFFING

POLISHING AND BUFFING

AUTOMATIC BUFFING

Automatic buffing offers a number of advantages, chief among which are the increased production and uniformity of output. Again with automatic machines the workman of ordinary ability can turn out a creditable product. As a rule any circular shaped article that does not present sharp depressions can be buffed automatically. The function of the machine is to rotate work as it is brought in contact with the wheel.

At the plant of the Aldrich Mfg. Co. automatic polishing is followed to a great extent in the manufacturing of sheet metal articles. The accompanying illustration is a layout for the operation which consists of buffing the insides of copper electric radiator bowls. The layout embodies two buffing machines so that the operator can load and unload one unit while the other is in operation. Various kinds of chucks are used for locating the work, the design depending upon the shape of the piece. Generally speaking, a quick acting plant fixture gives good results.

In finishing many pieces that are buffed automatically it is impossible to make the wheel cover the entire surface of the work at one setting. In polishing the pieces under consideration three cuts are taken, as shown in the accompanying illustration. The first cut polishes as much as possible of the bottom and the inside surface. In the second cut the location is changed so that the wheel bears nearer the rim. The third cut is for the purpose of polishing the rim.

The buffing wheel is stitched muslin, 14 inches in diameter and operated at 2200 revolutions per minute. This speed is a peripheral travel of approximately 8000 feet per minute. Two operations are performed at each setting, cutting down the tripoli and finishing with lime. A final coloring operation is done by hand with rouge. The tripoli and lime are applied to one wheel, one after another. Thus after cutting down the tripoli, lime in cake form is applied to the wheel. This practice has been found to result satisfactorily and it is a great saving over the method of using a separate wheel for each abrasive, which would necessitate the installation of a large number of machines to take care of the given output. The buffing machine is a comparatively simple

appliance consisting of a base carrying a saddle that is adjustable two ways. The adjustments are controlled by screws and hand wheels. The chucking head which is mounted over the saddle can be adjusted radially. The work spindle is driven by a $\frac{1}{4}$ -horsepower electric motor or by an overhead drive. The work is rotated at a normal speed of 25 revolutions per minute.

In finishing the bodies of copper kettles 14 inches in diameter, the work is held over a chuck, while a felt-backed pressure device is utilized to keep the part in place. This arrangement is better than a clamping fixture for this particular piece. The work can be set forth past the wheel automatically when desired. This arrangement is not always used, however, in finishing pieces that can be brought into direct contact with a wide-faced wheel. In cases of this kind a polisher is guided by experience in setting up the job so that the machine will finish the largest number of post possible in a given time.

Automobile hub caps can be buffed advantageously on automatic machines. The production of hub caps is enormous as each new car requires four while the replacement business is also heavy. The brass hub cap for one make of modern price car can be purchased for a few cents and when it is considered that three drawing operations, one threading operation, one trimming operation and two buffing operations are involved, to say nothing of nickel plating, the value of semi-automatic machinery is apparent. Heretofore the most expensive operation involved in the manufacture of hub caps is buffing before nickel plating. The material is sheet brass and as it comes from the drawing dies its surface presents irregularities and slight imperfections that must be removed. Otherwise these imperfections will show plainly after nickel plating.

In buffing hub caps the machine is equipped with two heads, one for each buffing wheel. Each head is fitted with two stations. The operator slips a cap over a holder on the end nearest to him where it is located by the interhexagonal part. The head is then given a half revolution which brings the work in contact with the buffing wheel. The part rotates slowly so that every portion of its surface is finished. While the part is in process of buffing the operator changes the work on the loading station, that is the one away from the buffing wheel. Then he steps over to another side of the machine and performs the same operation again. Thus

he keeps two hub caps in process of buffing at one time. The wheels are stitched muslin, 16 inches in diameter, 3-inch face, operated at 2200 revolutions per minute. This spindle speed imparts a peripheral travel of 9215 feet per minute. This operation is economical, as one man can finish 150 hub caps an hour.

Automatic buffing can be employed advantageously for finishing metal strips on machines such as the Mitchell strip buffer. The strips to be buffed are placed on a conveyor belt at the left-hand end of the machine which belt carries the work past the wheels and discharges it at the right-hand end. The wheel axes are parallel with the line of motion of the work. The rate of feed is dependent on the nature of the work being buffed, any changes in which can be accomplished by changing sprockets on the conveyor drive. The Mitchell machine is equipped with four polishing stations, two wheels each being driven by a 10-horsepower motor. Each pair of wheels rotate in opposite direction, the method of buffing being for one pair of wheels to engage the strip of work from approximately the center to one outer edge, and the other a pair of wheels approximately from the center to the opposite edge.

AUTOMATIC POLISHING

Automatic buffing and polishing often are defined as one operation, but a radical difference separates them. Buffing is performed on cloth or felt wheels to which the abrasive, such as rouge or lime, is applied locally, while polishing in the strictest sense of the word is done on wheels set up with abrasive and glue.

Several types of automatic polishing machines are on the market, while also a large number of home-made appliances are in use. An interesting example of automatic polishing in the cutlery trade consists of polishing the blades of knives on Jones polishing machines. Each machine carries two canvas polishing machines while the work is mounted on a suitable holder and set between the two wheels, one wheel polishing each side. Thus two sides are finished simultaneously. These wheels operate at a peripheral speed of approximately 5000 feet per minute. In one plant, the wheels are set up with No. 50 Turkish emery for the first operation, while the second polishing is performed with the wheels coated with No. 180 emery. A further operation is performed with 00 or 000 emery and in this case emery cake also

is applied to their wheel. This results in a very high commercial finish. The fact that the wheels are somewhat flexible enables them to flatten out as they pass the work, thus a comparatively wide surface can be finished at one setting of the work. For finishing very wide knives, however, it is customary to put them through each operation twice, a different set-up being provided in each case.

One type of Excelsior automatic polishing machine is equipped with a conveyor belt fitted with lugs for carrying the work under a series of ten polishing wheels at the rate of 25 feet per minute. This machine handles a wide range of work. Each wheel is from 10 to 16 inches in diameter and individually driven by a $7\frac{1}{2}$ -horsepower motor. Straight-line scratches are eliminated by a device that vibrates the feed table sidewise.

The Ross automatic polishing machine works on a novel principle in that it is equipped with a rotary sectional magnetic chuck 100 inches in diameter which carries the work under four polishing stations. The polishing wheels are carried on spindles mounted in yokes. The table speed varies from $\frac{2}{5}$ to $\frac{2}{3}$ turns per minute, depending on the nature of the work. Production on this machine varies with the nature of the work. Seven-inch carpenter plane blades are finished at the rate of 500 per hour. This machine also is fitted with vertical spindle carrying ring wheels, ring abrasive wheels for performing grinding operations before polishing.

At the plant of the Ireland-Matthews Mfg. Co. a large number of automatic polishing operations are carried out, one of which consists of polishing metal base rings for heating stoves. These rings are nickel plated but before plating the surface must be highly polished. This machine carries six wheels and automatic means for presenting the work to the wheels was designed by the company's engineers. It can be arranged for polishing round or oval rings. Each work holder is carried by a slowly revolving work head at a speed of about 12 revolutions per minute. The ring is held in place on the holder by a clamping device, that consists of two arms equipped with rollers that bear against the work to hold it in place. While the holder with the work revolves the arms remain stationary. They are thrown in position against the work by a quick-acting hand lever. As the work revolves slowly its axes changes from the horizontal to

the vertical position, the object of which is to bring every part of the work surface in contact with the wheel.

The plane of the wheel spindle also changes to let the wheel face bear on the work, thus as the oval work revolves the wheel raises and lowers automatically. The wheels are 6 inches wide. The first wheel is canvas set up with 100 emery, the second is canvas set up with 140 emery, the third is canvas used with number 140 emery cake, the fourth is canvas used with 160 emery cake and the fifth and sixth are bull-neck leather used with 160 emery cake. These wheels are operated at 2200 revolutions per minute, imparting a surface speed of 6933 feet per minute. In operation the operator places a ring on the first station and as soon as it is polished he removes it and puts it on a bench behind the second station. Then he passes to the second station, removes a finished ring and places it on a bench back of the third station. Thus he walks back and forth changing the work from one station to the other.

Automatic polishing machines also are used extensively for polishing stove plates, particularly top assemblies. Such machines carry from one to four wheels which are reciprocated back and forth over the work automatically while the work is moved sidewise.

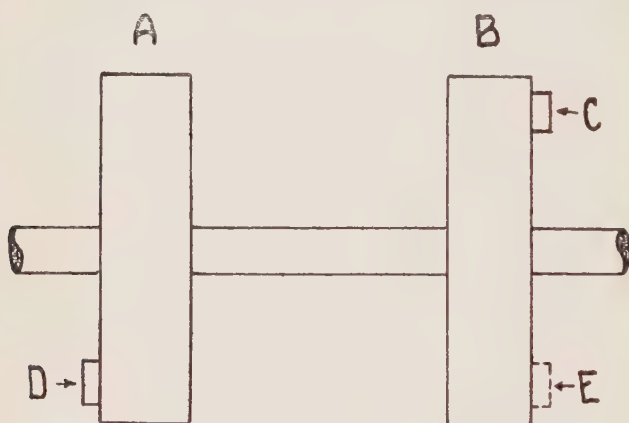
The Schulte polishing machine is used for finishing sheet steel. It embodies means for feeding the work under one or more large polishing drums. The advantage of polishing sheet material before fabrication is apparent, as it represents the difference between finishing a flat or an irregular surface. Again, if parts are to be formed from sheet metal under drawing dies, the smoothly polished stock will flow much better than unpolished material.

BALANCING POLISHING WHEELS

Correctly balanced polishing wheels are a necessity for a wheel that is out of balance pounds the work and does not cut effectively. If it is badly out of balance it is dangerous to use. Devices used for balancing polishing wheels are of two kinds. One type is the so-called balancing ways. The upper surfaces of the ways must be leveled accurately. The polishing wheel is placed on an arbor and the arbor set on the balancing ways. The wheel will rotate until it comes to rest with the heavy side down. Then,

in the case of ordinary wood wheels, the operator tacks a lead weight opposite the heavy side to compensate for it. The weight should be such that the wheel remains stationary when placed in any position on the balancing ways. Such a wheel is said to be in standing, or static balance.

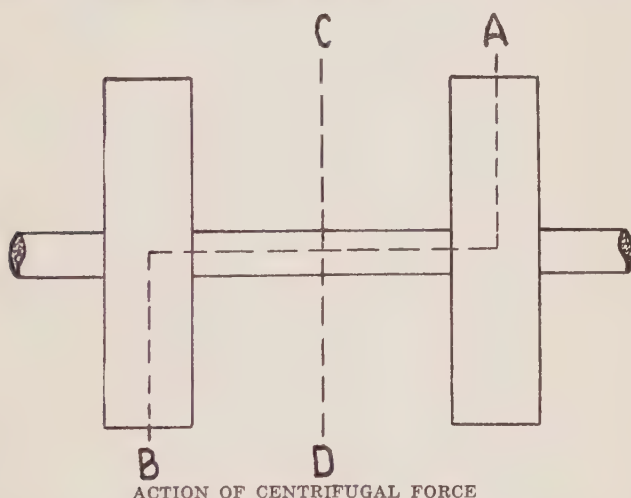
An improved balancing appliance permits the arbor to be set on rollers. These rollers are ball bearing and turn very easily. The advantage of this device is that it can be used anywhere without leveling. Otherwise, its operation is the same as that of the ordinary balancing ways. It will not be out of



PRINCIPLE OF DYNAMIC BALANCING

place here to explain the difference between static and dynamic balance, which means the same thing as standing and running balance. In any article, such as a polishing wheel, where the diameter exceeds the width by a number of times, if the wheel is put in good static balance it should run satisfactorily, without vibration, that is if operated at a normal speed. If a very slight amount of out-of-balance is in evidence, the machine spindle and machine base should absorb this. However, let it be assumed for an illustration of the principles of dynamic balancing that two polishing wheels, A and B, in the accompanying illustrations, were mounted on one arbor. Now suppose a weight is attached to one wheel at C; the two wheels and the arbor can be put in standing balance by attaching another weight at D, on the opposite wheel on the opposite side. Now let it be assumed that the

part is put on a running balancing machine. It will show very much out of balance for line *A-B*, though centrifugal force tends to straighten out, in an attempt to assume the position shown at *C-D*. For this reason the polishing wheel shaft and assembly would vibrate very much on the balancing machine. To bring this part in running balance it will be necessary to place the offset weight directly opposite the first weight that was added, at *E*. Then the piece would be in running balance because the centrifugal strain would be exerted in one way only. Thus it is apparent that comparatively thin polishing wheels can be balanced satisfactorily by the standing method, but if a wheel is com-



paratively wide, such as used on the Schulte machine, it may be necessary to put it in dynamic balance.

The question sometimes is asked if any good would result from balancing ordinary polishing wheels dynamically after they were put in standing balance. No good would be accomplished and the extra balancing operation would be a waste of time. However, when the standing balance method is used the results are not always as the operator desires, for in his haste he sometimes does not put the wheel in a perfect standing balance, while it may be near enough, however, so that the machine in the spindle absorbs the vibration. If the running balance method were used altogether in place of the static methods perhaps excellent results would be derived, as it would put the wheels in a

perfect running balance so that all vibration would be eliminated.

In considering some of the larger wheels used for polishing such as those 30 inches in diameter and 6-inch face, it is evident that they should be balanced very carefully. On some makes of wheels having iron centers, holes are provided in which lead weights can be placed. By this means the wheel can be balanced very accurately. In some polishing rooms it is customary to have the wheels balanced directly after they are set up, the work being performed in this department. As a general rule, however, the polishing machine operator, himself, balances a wheel as soon as he takes it out of stock. Either method is, of course, productive of good results and it is all a matter of opinion and routine. The fact remains, however, that unbalanced wheels should never be used as they waste abrasive and, under some conditions, they are dangerous. To the best of the author's knowledge no machines have been placed on the market for the running balancing of grinding or polishing wheels but in the future such units may be introduced and used freely. It is hard to predict accurately what will happen in the abrasive industry, as great strides are being made yearly and the fact is becoming recognized that the better balanced the wheel, the better will be the output.

BINDERS FOR BUFFING COMPOUNDS

Binders used for making buffing compositions should possess several characteristics. The finished cake must be sufficiently hard to avoid at ordinary temperatures breakage, crumbling and in application to the wheel. The melting point must be correct so that the right amount of material can be applied to the wheel. If the binder is too soft it will wear away too rapidly. The binder must be of a nature to be taken up by the wheel readily and it must possess a certain amount of lubricating quality to avoid undue heating. It must not glaze the wheel or accumulate in hard particles. Also it must not smut or burn the work or leave a noticeable deposit on the work. If after buffing the work is to be cleaned for plating, the binder must be of a nature to saponify readily so that it can be removed by the cleaning solution. Quite a variety of materials are used for the binders in question, a few of which follow.

Stearic acid is a complex organic acid material at normal temperatures presenting a white crystalline appearance with

waxy characteristics. It is manufactured from tallow by the process of saponification as also are oleic acid and glycerine. Also it can be prepared from other substances by distillation. It is hard, but not brittle and it permits the cake of abrasive material to be worn down by the wheel without breaking or crumbling. This material is comparatively expensive while also its price fluctuates to quite an extent. Petrolatum is Pennsylvania paraffin-base material and while it is expensive it makes an ideal binder for polishing compositions. It adheres well to the wheel and lubricates without charring or glazing. Tallow should be of the open kettle rendered edible type and of the best quality. Paraffin is a pure white wax distilled from Pennsylvania oil.

BUFF STICK

A device used for truing cloth buffing wheels. A buff stick is made by coating a hardwood stick, about one inch square and a foot long, with glue and abrasive such as emery or carbide of silicon. Several coats of glue and abrasive are applied successively. When the stick is brought against the wheel periphery it cuts away the ragged fibers of cloth, forming a flat or special-shape surface as desired. In other words, a buff stick bears the same relation to a buffing wheel as does a star-wheel dresser to a grinding wheel.

BUFFING SUGGESTIONS

If the buffing wheel is operated at too low a speed, the work tends to tear the abrasive away. If the speed is too high the buff will be burned. Low speeds are permissible for small work and also for comparatively small diameter wheels. Average peripheral speeds for buffing range from 7500 to 10,500 feet per minute. A little buffing composition should be applied at a time by holding the cake lightly against the wheel. Too much pressure will result in an excess amount of abrasive material being used and the excess grease will smut the work preventing abrasive action. Again, the excessive friction set up by too much pressure will waste the material which will fly off the wheel. Different speeds should be used for cutting down and coloring and a separate wheel for each operation is preferable. When a buff becomes greasy, it should be cleaned with a buff stick or an old file. Then by applying the buffing composition

lightly and quickly a few times the wheel will be brought back into working condition.

COST OF BUFFING

The cost of buffing operations is dependent on many items such as wages, overhead, fixed charges, cost of buffs, value of work that will not pass inspection, etc. Thus the cost per finished piece depends on the number of articles buffed per hour, the value of buffs and buffing material used, etc. In general, it can be stated that low-price materials are dear in the long run so that it pays to buy first-class supplies.

GRAIN SIZES FOR POLISHING

The exact size of abrasive grain to be used for a specific polishing operation can be determined by experiment only. However, in considering a number of polishing operations the Abrasive Co. suggests the following sizes. The range is between the numbers used in ordinary practice:

Part polished	Grain size
Aluminum castings	46 to 180
Aluminum ware (stamped)	60 to FF
Auger bits	60 to 120
Auto parts	24 to 180
Axes	24 to 150
Balls (steel)	60 to FFF
Bicycle parts	60 to 120
Bolts and screws	46 to 90
Brass	24 to FFF
Bronze	24 to FFF
Builders' hardware	60 to 220
Bumpers (auto)	46 to 60
Butchers' tools	46 to 150
Carpenters' tools	36 to 180
Cash registers	60 to 150
Cast iron	46 to FF
Coffin hardware	60 to FFF
Copper	46 to 180
Cultivator discs	24 to 36
Cut glass	90 to 120
Cutlery	20 to FFF
Dental instruments	60 to 220
Disc wheels	46 to 60
Drills (flute scouring)	36 to 60
Electric irons	60 to 80
Electric fans	80 to 150

POLISHING AND BUFFING

Part polished	Grain size
Fiber	60 to 120
Files (renewing surface)	30 to 46
Firearms	46 to FFF
Fire extinguishers	60 to 150
Flat irons	60 to 80
Forgings (steel)	24 to 150
Furnaces	24 to 46
Garden tools	36 to 90
Gages (steel)	60 to FFF
German silver	100 to FF
Glass (beveling)	70 to 150
Glass (surfacing)	180 to FFF
Glass (cut)	90 to 120
Granite	60 to 90
Hammers	36 to 150
Hoes	36 to 100
Iron beds	46 to 70
Knives	12 to FFF
Lapping (steel)	90 to FFF
Lenses	60 to FFF
Lithographic stones	60 to 90
Locks	60 to 150
Machine parts	24 to 220
Marble	200
Masons' tools	60 to 120
Mattocks	46 to 120
Metal furniture	36 to 150
Mirror beveling	70 to 150
Monel metal	100 to FFF
Motor parts	24 to 180
Musical instruments	60 to FFF
Optical work	60 to FFF
Piano parts	90 to 220
Picks	46 to 120
Plate glass (beveling)	70 to 150
Plate glass (surfacing)	180 to FFF
Platinum	100 to FFF
Pliers	46 to 120
Plows	20 to 80
Radiators (iron)	46 to 60
Radio parts	60 to 220
Razors	120 to 180
Registers (heat)	60 to 70
Rubber (hard)	46 to FFF
Rubber tires (roughing)	10 to 36
Sad irons	60 to 150
Safe deposit boxes	36 to 150
Safes	8 to 24
Sandblasting	12 to 36

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Part polished	Grain size
Saws	60 to FFF
Scales	36 to 150
Screws and bolts	46 to 90
Sewing machine parts	60 to F
Shears	54 to FF
Shovels	30 to 120
Showcases	60 to 120
Silverware	60 to FFF
Skates	60 to F
Spark plugs	80 to F
Springs (leaf)	36 to 60
Stampings (brass)	46 to F
Stampings (steel)	36 to 180
Steel	24 to 150
Steel castings	12 to 24
Steel (high-speed)	36 to 120
Stoneware	24 to 60
Stove parts	36 to F
Surgical instruments	60 to FFF
Taps (flute polishing)	36 to 60
Tools	46 to 220
Tubing	24 to 180
Typewriter parts	60 to F
Vacuum cleaners	60 to 100
Valves	46 to 120
Vises	36 to 100
Wrenches	30 to 120

PNEUMATIC POLISHING WHEEL

A device of this kind incorporates a body which is mounted on the spindle in the usual way, and a pneumatic element interposed between the body and the abrasive band which performs the cutting. Such wheels are made in three grades of elasticity. They also are made in various sizes so that they can be used on polishing lathes or on flexible shafts.

POLISHING BELTS

Polishing belts are made of canvas or other woven materials. They are set up with glue and abrasive and are used on a belt polishing or strapping machine for finishing parts that cannot be handled on ordinary polishing wheels. They are made in various widths from $\frac{1}{2}$ to 4 inches.

POLISHING AND BUFFING WHEELS

Polishing and buffing wheels are of various kinds, each type being best suited for specific needs. Loose open buffs, sometimes called muslin buffs, are made of cotton sheeting, especially

adapted for cutting down metals with polishing composition. Buffs run in sizes from 2 to 20 inches generally.

Sewed-pieced sectional buffs are made of bleached and unbleached cloth. The sections are made of small pieces of cloth which are laid and stitched from the center to the periphery of the wheel. It is said that they hold the composition longer and cut faster than a loose buff.

Canton-flannel buffs is used for buffing where a soft wheel and a high finish is desired, such as on jewelry, brass bedsteads and automobile lamps. Such buffs are made of cloth with a fine nap and a heavy back. They are long lived. Eighteen ply is a favorite size.

Printer's ink buffing wheels are used for cutting down all kinds of brass castings with tripoli composition. They hold the composition satisfactorily. They are made in loose and pieced sections.

Spanish-felt wheels are made in three grades known as soft, medium and hard. Hard wheels are preferred for polishing operations as it holds the glue and emery a long time. Medium wheels are used for finishing flat surfaces and soft wheels for buffing surfaces having projections, indentations and beveled edges.

Mexican-felt wheels cost less than Spanish ones and they enjoy an extensive use. Mexican wheels are made of American-grown wool and they are used for similar purposes as the Spanish wheels, generally in cases where the finish is not so important.

Solid-canvas wheels are used for polishing plow parts, steel tools and metals with flat surfaces. They are made of heavy canvas duck put together with a waterproof cement making a slightly flexible surface. These wheels can be shaped to conform to various types of work.

Stitched and cemented canvas wheels are made up of several disks of canvas sewed together making a section. Several sections are then cemented together. This type of construction gives a more flexible surface than a solid wheel which has cement between each layer of canvas.

Loose canvas wheels are used where extra resiliency or pliability is required. Generally such wheels are cemented solid

for about half way between the hub and periphery. After such wheels are set up with glue and abrasive a yielding cushion is formed.

Muslin wheels are made of disks of muslin cloth stitched from the center to the periphery. They are made in sections the same as buffs and cemented to any desired thickness. They generally are dried under hydraulic pressure. They are used for polishing plow parts, tools, shovels, etc. They impart a good polish and adapt themselves to shaped work readily.

Solid-sheepskin wheels are made of disks of tanned sheepskin leather cemented together from the center to the periphery. They are resilient and adapted for fine polishing.

Sheepskin wheels stitched and cemented are made of whole disks of leather stitched together, the rows of stitching being from $\frac{3}{8}$ to 1 inch apart. These are durable wheels adapted to fine polishing.

Loose-sheepskin wheels are made of whole disks cemented at the center and sewed around the hole. They are used for polishing uneven surfaces. They also are made with rows of hand sewing, usually one inch apart.

Walrus wheels are made of walrus or seahorse hide. When this material is tanned correctly, it has a tough grain, but on account of its peculiar fiber the wheels are quite resilient. They are used for fine finishing of table cutlery, brass, silver and other soft materials. Also they are used in the manufacture of edge tools and hardware specialties. Such wheels can be supplied with shaped faces for finishing irregular work.

Wood wheels are built up of sections of carefully dried lumber about $\frac{3}{8}$ -inch thick laid so that the grain of each section is at right angles with the ones next to it. They are glued together and dried under pressure. They are furnished with iron centers and faced with oak tanned leather to which the abrasive is applied.

Paper wheels are made of strawboard. They are said to be excellent for hard work such as polishing plow parts, farm tools, etc. So-called felt paper wheels are used for finishing stove trimmings, etc.

Bull-neck wheels are made of bull-neck leather. They are used for finishing stove parts and also they can be used in place of felt wheels for finishing and coloring. They are solid

POLISHING AND BUFFING

leather and quite resilient. These wheels also are employed for a diversity of operations such as finishing brass goods, forged tools, etc. Their faces can be shaped.

Laminated felt wheels are made of disks of wool about $\frac{1}{4}$ -inch thick stitched together. They are used by cut-glass manufacturers, for finishing cutlery and for finishing stove parts, etc.

Compress polishing wheels are made with a clamp center which holds the periphery, made of a number of radial sections. The parts are under compression when the centers are put in place. These wheels are made in soft, medium and hard grades of various materials such as leather, felt, walrus hide, canvas, paper or muslin.

POLISHING AND BUFFING SPEEDS

No standard rule can be laid down for the speeds of polishing and buffing wheels, but according to Frederic B. Stevens, the speed should be governed by the nature of the work and the abrasive material used, fast speeds generally giving the most economical results. Mr. Stevens gives the following speeds for polishing and buffing wheels:

Diameter, inches	Revolutions Per Minute	
	Polishing wheels	Buffing wheels
8	3700	4000
10	3000	3600
12	2500	3200
14	2200	2900
16	1900	2500
18	1700	2200
20	1500	2000
22	1400	1800
24	1300	1700
26	1200	1550
28	1100	1450
30	1000	1350
32	950	1250
34	900	1200
36	850	1100

POLISHING COOKING UTENSILS

For polishing aluminum cooking utensils, such as pots, spiders, etc., a canvas wheel set up with a manufactured alumina abrasive in 80, 90 or 100 grain can be used. The grain size depends, of course, on the amount of stock to be removed and the finish desired. In some cases a little experimentation is

necessary to determine the most satisfactory size. If the corners are square, the wheel face should be beveled slightly to cause the abrasive to reach well into the angles. The bottom of the work can also be cleaned in the same operation, if desired, by changing slightly the construction of the canvas wheel. This one operation will impart a fair finish. If a buffed finish is desired, a canvas wheel set up with 150 grain should be used after the roughing operation. During the roughing and finishing operations the wheel, or the work, should be greased. Otherwise the aluminum, regardless of the grain size of the abrasive used, will heat and drag. Under some conditions the casting might be forced out of shape. Special buffing machines are used for operations similar to the foregoing.

POLISHING AND FINISHING BUMPERS

Bumpers preferably should be polished on an automatic machine, according to Andrew V. Re. This, of course, also applies to the brackets and bolt heads if they are highly finished. First of all, the wheels must fit the work, regardless of whether the bumpers are flat or with a high ridge or groove. The automatic machine should be of a type that can run ten to more bumpers at one time. Start the first operation with a solid grinding wheel about 60 or 80 grain. This operation cuts off the scale and saves time on the other wheels.

The second operation is done on a canvas wheel. This wheel should be a good grade of canvas set up with 60 or 80 abrasive and used dry. Care must be taken not to let the abrasive wear entirely away from the face of the wheel. When the abrasive is worn out it will not cut and will heat the work on the wheel, which may take fire. In this event one to two inches must be cut off to get down to a good surface again. The third operation is done on a leather-faced wheel set up with No. 120 abrasive. The fourth operation is on a No. 150 oil or grease wheel. The fifth operation is the so-called coloring operation. This wheel is set up with one-half of No. 150 and one-half flour abrasive mixed well together. Steel bumpers thus buffed will have a good luster. The color wheel can be greased with a grease stick followed with an application of charcoal.

POLISHING HEATER PARTS

Polishing and buffing operations are followed extensively in the manufacture of heater parts. Polishing is employed to level surfaces before nickel plating, while buffing brings out the high luster after the plating operation is completed. Beautiful oxidized effects also are possible through the employment of abrasive processes before and after the metal is treated.

Numerous small parts are polished by tumbling with water and lumps of sandstone in mills provided for the purpose. They are made of boiler plate about 24 inches in diameter and 5 feet long, each being fitted with a gate made tight by means of a rubber gasket as a means for loading and unloading. The parts are tumbled from 40 to 45 hours in the sandstone, a quantity of water also being introduced. The object of the water is to facilitate the abrasive operation and also it keeps down the dust. After the parts are tumbled in this manner, they are plated and then transferred to the buffing mill, where another tumbling operation is performed. In this case no abrasive is used, but each mill is supplied with a liberal amount of leather scrap. Parts thus treated have a very nice finish.

The lumps of sandstone used the foregoing operation cannot be selected by a haphazard method, as the stone must be particular grit. The material comes in fairly large lumps which are crushed and then broken by hammer blows. In this manner an abrasive of just the right size is crushed. In the operation of tumbling the parts in water, the abrasive lumps are reduced to a fine powder which, of course, forms a sludge with the water used in the tumbling barrels. This material is not reclaimed.

A typical operation is that of polishing of cast iron preparatory to plating or oxidizing. This operation generally is performed on canvas and linen wheels, 12 to 18 inches in diameter; 1½ to 3-inch face. The wheels are set up with 46, 100 and 140 emery grain. Canvas wheels are used for roughing, linen for first oiling, felt for second oiling and felt for coloring. When it is necessary to polish aluminum, 140 grit material on linen wheels is used first, next 150 material on felt wheels followed by a buffing operation with a white compound.

The beautiful finish called oxidizing is a simple abrasive process. First the part, assuming that it is cast iron, is polished

according to the method just described. Then it is plated in copper or brass before dipping in oxidizing solution which may be copper or brass. Next the piece must be *high lighted* by buffing spots on a felt wheel, 9 inches in diameter, 1-inch face with white finishing material. Of course, in an operation of this kind the workman has an excellent chance to exercise his artistic ability, for the high-lighted spots are spaced by his eye and the entire operation is performed to suit his individual taste.

POLISHING PLUMBERS' GOODS

Plumbing goods such as bibbs, basin cocks, elbows, etc., generally are machined on a monitor lathe, while the polishing of the bodies, stems, bonnets, etc., is done separately. The parts first are couched out on a solid wheel from 6 to 8 inches in diameter and from $\frac{3}{16}$ to $\frac{1}{2}$ -inch wide, 70 to 80 grit. The wheel is mounted on a small polishing lathe and operated not faster than 1000 revolutions per minute. The face of the wheel should be formed to the desired shape with a dresser. The wheel face should be square for cutting out the roughness of elbows near the beading. A round-face wheel is used on bibbs.

The next operation consists of putting the parts over a sectional set-up wheel which can be made of sheets of shirting glued together. In making up such a wheel two plates should be provided. These are iron, round or square 20 inches in diameter and about $\frac{3}{4}$ -inch thick. The lower plate should be drilled and reamed to accommodate a bolt which is fastened securely in place. The diameter of the bolt corresponds with the diameter of the polishing lathe spindle. The upper plate is drilled in the center so that it slips in place over the bolt easily, while a nut is supplied to bring about the necessary pressure required.

The buff sections should be 12 to 14 inches in diameter for finishing the class of goods in question. In making up the buff wheel, a sheet of shirting is placed on the lower disk and a coat of glue is applied. Another sheet is placed in position and glued, and so on until the wheel is built up to the desired thickness, which should be from $1\frac{1}{2}$ to 2 inches. Then the top plate is set in place and the nut screwed down tight. The wheel should be left in the press until it is thoroughly dry.

After removing the wheel from the press it is balanced and then mounted on the polishing lathe spindle and the face trued

off smoothly. Then the sizing coat of glue is applied and the lathe is run until the glue is dry. Next apply a piece of pumice stone lightly to the glued surface. Too much pressure will heat the glue unduly. The wheel now can be removed from the lathe as it is ready for setting up.

A word regarding glue will not be out of place. A cheap glue always is the most expensive in the long run as a larger quantity is used and again such material wastes the abrasive. If the glue is too brittle it can be made flexible by adding a small quantity of glycerine. Either ground or flake glue can be used. Flake glue, however, requires more soaking than the ground material. Ground glue can be soaked in cold water from four to five hours, while flake glue requires from 12 to 16 hours at least. The temperature of the glue never should exceed 150 degrees Fahr., and it should not drop below 135. Never permit glue to boil. Do not make up more glue than will be used immediately. Fresh glue should be made up every day.

In setting up a wheel, it is coated with glue and rolled or pounded into the abrasive. The trough that holds the grain should be long enough to permit the wheel being rolled its entire circumference. In drying the wheel, a temperature of 80 degrees Fahr. is satisfactory. When dry, the wheel is ready for the second coat of glue and abrasive. Four, five, and even six hours are necessary for proper drying. Wheels should be set up by an experienced man. This will result in economy and an increase of efficiency in the polishing department. Cold air should not be permitted to strike the wheel when setting up as it will chill the glue. Such a wheel will not hold its abrasive coating. Too much moisture in the air will prevent the glue setting properly. Again, a wheel that has been dried in an unduly hot, damp atmosphere invariably is short-lived.

The wheels thus set up are used for roughing or as greased wheels. Roughing wheels generally are set up with No. 120 abrasive while No. 150 is preferred for greased wheels. On the so-called couching out operation, round-nose wheels generally are used. It will be found that a felt wheel gives good results on this operation.

A two-wheel job involves almost as much labor as required on a three wheel operation, counting the work done on the pre-

liminary solid wheel. This wheel should not be counted, however, because if one undertakes to rough out the beading without grinding on the solid wheel first, he will cut away the abrasive on the set-up wheel in short order. It is customary to use a buff about as thick as can be grooved into the couch. In this manner the operator will gain time and do satisfactory work.

Bonnets are buffed by placing about 20 at a time on an iron rod with a wood handle. Without such a handle the iron becomes heated unduly so that it is hard to hold properly. As the bonnets are machined in the monitor lathe, only one polishing operation is necessary. For this work a grease felt wheel, $\frac{3}{4}$ -inch face with a round nose set up with No. 150 abrasive, will be found satisfactory.—Andrew V. Re.

POLISHING RADIATOR SHELLS

Radiator shells can be polished successfully by the so-called two-wheel operation. If the shells are not rough, No. 150 abrasive can be used for the first operation, followed with No. 180 abrasive for the second and last operation. However, should the steel be rather rough and pitted, it will be necessary to polish on a No. 120 dry wheel for the first operation. The so-called wet or grease wheel used for finishing is made by using emery grease cake, or mutton tallow and tripoli will do.

Work polished on wheels treated in this manner will not show scratches when buffed. One must try always to cross each operation of polishing. For instance, if the first operation is done straight up and down, the second operation should be done on about a 45-degree angle.

When polished, the shells are ready for the soaking tank, and then the hot copper combination cleaner. The copper solution should stand 120 degrees to 140 degrees Fahr. In some cases the shells only are plated in the alkaline copper, 10 to 15 minutes and afterward they are plated into an acid copper, colored, buffed and nickel plated or chromium, whatever the case may be. In most cases an acid copper is not used. Therefore a nice heavy alkaline copper is placed upon them, colored, buffed and nickel plated.

In some cases the copper is not color buffed before nickel plating. However, if the copper is nice and soft as it should be, one can color buff it in a very short time. Afterward it is

nickeled and recolored. The nickel is buffed in a very short time to a high lustre. Not much nickel is removed because there already is a high life on the copper and if the nickel is in good standing, the work will be quite bright and not rough and milky. Hence, when one has a nice nickel that can be colored easily it is not necessary to buff off a large amount of nickel to get a lustre.

POLISHING ROOM LAYOUT

In many instances, but little attention is given to the layout of the polishing room; this department being located often where it is most convenient, sometimes in the basement or other out of the way place. If efficient results are to be obtained, however, great care should be exercised in the layout of the polishing and buffing departments. Polishing and buffing are wholly manual operations and naturally if satisfactory working conditions are not maintained, maximum production cannot be expected.

The layout of the polishing room, of course, depends in a great measure on the nature of the work to be handled. In cutlery practice, for example, it is common practice to arrange the polishing jacks in a row just back of the windows, a line shaft being directly under the windows. While this often is a satisfactory arrangement, it is well to bear in mind that the operators are working against a direct strong light. Better results are obtained, however, when the polishing machines are located so that the operators are given the benefit of a side light.

In some instances the arrangement of the machines, as in a shovel factory, is for crews of four operators each. Each man performs a different task, the first being grinding the strap of the shovel on a solid wheel, the second polishing the strap on a set-up wheel, the third finishing the strap on an abrasive belt and the fourth finishing the handle.

Whatever the arrangement, ample room should be allowed between the machines for handling the work. Otherwise, production will be curtailed. If belt-driven machines are used, and if the belts are exposed, they create a large amount of dust. If the belt drive must be utilized, better results are obtained by providing machines with a closed interior, the drive shaft

being located on the ceiling of the floor directly beneath the machine. The belt being enclosed, it has no chance to stir up dust. Electrically driven machines, eliminate belting altogether. The electric drive, however, possesses one disadvantage, in that desired speeds are not always obtainable.

Adequate lighting should be provided, for it must be borne in mind that daylight cannot be utilized during the winter months. It is well to consult a lighting engineer on this point, always bearing in mind the fact that the large amount of manual labor involved calls for efficiency at every point. The lighting engineer can specify the correct kind of lighting which will give the best results.

POLISHING STOVE PARTS

The polishing of nickel plated stove parts constitutes an important branch of abrasive practice. The character of the polished surface depends largely on subsequent operations, especially the preparation of the surface before it is plated. To polish stove parts economically comparatively smooth castings are essential and the surface to be plated should be adapted to polishing; the two foregoing requirements are dependent upon the foundrymen and patternmakers. The grain of the iron should be so close that when it is polished it will present a smooth surface. A patternmaker is depended upon to design the parts so that uneven surfaces can be polished readily. In other words, the design must not have deep impressions that cannot be reached by polishing wheel. Also crevices which would retain the abrasive must be eliminated. In many instances where the grain structure of the castings is correct the iron is too hard for satisfactory polishing. If the iron is poured too hot the castings are frequently covered with a hard scale that is detrimental to rapid polishing and while pickling and sandblasting cannot be depended upon to soften hard castings it will remove the hard scale to a certain extent. The pickling process was used entirely for the work in question many years ago, but at the present time the sandblast method has taken its place to a great extent.

High-grade nickel plated stove parts require considerable polishing where successive wheels often being employed is as follows: Roughing, dry fining, second fining, oiling, greasing

and finishing. First, our roughing operation is performed on a canvas wheel set up with 60 or 90 abrasive grain either emery, manufactured alumina or carbide of silicon. The wheel must be resilient so that the abrasive grains are given an opportunity to reach depressions in the work. The second operation or dry fining is performed over the canvas wheel set up with a 60 or 90 grain and in carrying out this work the parts should be held at right angles to the previous locations so that the wheel cuts are carried across and not parallel with the cuts made in the previous operation. In the third or second fining operation a still finer grade of abrasive is employed and when possible the wheel cuts are made to intersect the cuts made by the foregoing operation. For the fourth operation, namely oiling or greasing, polishers are not in agreement on the type of wheel to be used. The wheels can be set up with 120, 150 or 180 abrasive. After setting up the wheels are worn down somewhat by actual polishing to glaze the surface slightly then the wheels are treated with emery cake. Before greasing the work should present fine lines only. However, if the previous operation has not been performed properly and if the work presents these indications these parts should be polished crosswise. If the wheel clogs it can be cleaned with lump pumice.

For the fifth or fining operation a felt grease wheel gives good results. The wheel that has been used for a comparatively long time gives excellent results. This operation differs from that of greasing as a fragment of flint is worked over the wheel periphery, imparting a high polish. When the work is brought in contact with this surface a lustre is imparted to it and scratches that may have been left by the former operation are removed. A higher polished finish on the casting insures a fine nickel finish.

If the foregoing sequence of operations is more extensive than the class of work warrants a four-wheel procedure can be substituted and omitting the second fining or finishing. In some stove plants the work is rubbed fine and second fine while in other establishments the procedure includes roughing, fining, greasing and finishing. The first procedure is preferable as more scratches are taken out so that when the grease wheel is used the second fining wheel is eliminated and a high finish can be obtained by buffing. A low grade of polishing preparatory to nickeling some-

times is performed with two or three wheels. If three wheels are used, the operation should constitute roughing, dry fining and greasing. Certain factors should remain constant regardless of how many wheels are used. These include the sizes of the abrasive grains on the first and final wheels. The accompanying table gives correct abrasive grains for the 5, 4 and 3-wheel methods.

FIRST CLASS POLISHING

Operation	Grain size
1—Roughing	60
2—Finishing	90
3—Second fining	100
4—Greasing	120 to 150
5—Finishing	150 to 190

SECOND CLASS POLISHING

1—Roughing	60
2—Finishing	100
3—Greasing	100 to 120
4—Finishing	120 to 150

THIRD CLASS POLISHING

1—Roughing	60
2—Finishing	100 to 120
3—Greasing	120 to 150

It is not considered good practice to use mixed grain sizes as, of course, the grains leave comparatively deep scratches and a mixture of 60 and 90 emery will leave scratches as deep as a straight 60 grit. For example, if a quantity of No. 60 abrasive becomes mixed with a quantity of No. 90, the only logical procedure is to rate the entire mixture as No. 60. Probably it will be more economical to discard such a mixture entirely because its use as No. 60 would entail an extra expense as the mixture would not cut as fast as a 60 grit. It should not be used as a No. 90 as it would leave No. 60 scratches on the work.

Iron and steel parts that are to be polished preparatory to plating may be in a condition unfit for the first or roughing operation. Insufficient cleaning by sandblasting may result in particles of sand adhering to the castings, or the work may be rusty or greasy. If sand is present, the part should be resandblasted and then washed in boiling water. Rust can be removed with kerosene or gasoline. However, if the rust coating is comparatively thick, it may require scraping. Animal or vegetable grease can be removed with boiling caustic soda or potash. On the other hand, mineral oil can be removed with gasoline.

While the abrasive grain sizes given in the accompanying table should be productive of economical results, local conditions also must be taken into consideration in adapting the sizes to a specific operation. For example, the work may be too rough to be cut with No. 60 grit in the first operation and a coarser size should be substituted. Conversely if the work is comparatively smooth, a finer grain than 60 sometimes can be employed to advantage. The polisher should exercise judgment in changing from one grain size to the next, ever bearing in mind the fact that ultimately Nos. 150 or 180 will be used. If the grain sizes are too fine, the polishing time is lengthened materially. In some instances the grain is so fine that the scratches left in the preceding operation are not removed readily. Judgment must be exercised in selecting grain sizes and experiments often are necessary to determine the most efficient.—J. F. Springer.

PRACTICAL POLISHING HINTS

In polishing gold and silver, iron oxide (rouge) is the ideal material. For nickel coloring, the metal magnesium, in lime compositions having a great affinity for nickel, is the ideal. For steel, whether stainless or carbon, the metallic oxide chromium has been found the most efficient and simplest medium for bringing out the surface and color, for the reason that chromium has a perfect affinity for steel under conditions. But in order to get the best results from the last operation, certain definite rules must be followed in preparing the work for the final application of the finish with chromium.

Assuming that the quality of the steel is of the best, there are even slight variations in nearly all metal products which will slightly influence the various processes in preparation for finishing. Therefore, due regard to this must be given by the grinder and polisher. It is, of course, understood that during the grinding process the steel be not burned by overheating, and this equally applies to the processing at the final polish. It can be easily demonstrated that, as the metal is cut away on the surface of steel, the surface will present a varied appearance, which is due to the difference in the shape and structure of the steel cell or scale. This condition is very noticeable in stainless steel, and is brought out in an exaggerated condition due to the very high mirror-like finish, which readily reveals and magnifies any

imperfections below the polished surface. Therefore, it is very essential that we have a perfect bottom on the work to be polished.

Producing the bottom is the work of an expert, and is, of course, the most important part of the entire process. There are various natural and synthetic abrasives on the market, some of which are perhaps better than others; but it is necessary to choose the proper grade, and each manufacturer must decide upon the one which meets his requirements fully. However, there is one point to be watched with great care, and that is that the abrasive must have grains of uniform size in order to prevent a surface of different size cuts or scratches; for one off-sized grain will destroy the entire labor, especially during the last process before finishing, and, as stated previously, any abnormal mark or cut will be exaggerated and made plainly visible after the chromium is applied.

"All is not gold that glitters." Neither is all chromium suitable for polishing steel; for if there should be traces of other metallic oxides, sulphur or other foreign matter in the chromium when used, certain changes in the surface appearance of the polished article will take place, sometimes at once and quite often at a considerable time later. This will mar the appearance of the work and materially reduce its selling value. The explanation is that during the polishing process some of the chromium amalgamates with the steel, and should there be other metal content this also would enter into the surface of the steel and gradually, by chemical or atmospheric action, show up on the work in the form of stains, spots and other detrimental effects, and your stainless steel is in reality not stainless.

No two manufacturers, given the same materials to work with, will obtain identical results. This can be noted by a careful comparison of articles of a similar nature made by various concerns. There are several reasons for this, and the most important one is the fact that the last operation or bottom was carelessly or incompletely done and the resultant finish with chromium was not up to standard.

The writer during experiments has noted the fact that carbon steel after polishing with chromium will hold its lustre and keep from spotting almost indefinitely. This is due to the fact, as stated before, that some of the chromium has amalga-

mated with the steel and has produced a stainless steel coating on the surface. We have also noted that keen-edged articles will hold that edge much longer, due to this same fact. In other words, the keen serrated feather-edge of any blade is protected against oxidation or corrosion by the stainless quality imparted by the chromium.

Now, in order to get the results desired we have come to the following conclusions: First, there is a certain natural or synthetic abrasive, which you must determine by test, which will produce the best bottom, and you cannot determine this without making many tests. Also, the class of wheels and proper speed of same must be considered. Secondly, a loose-sewed muslin buff of good firm weave is recommended, running at maximum speed at or near to 3500 revolutions per minute.

Speed is considered essential, for with speed there is perfect melting of the fat content of the crocus, making it adhere uniformly to the buff. Also, less pressure of the article to the buff is required while polishing. However, the main feature of the speed is the fact that sufficient heat can be so generated as to cause a combining of chromium into the surface of the steel without the danger of overheating the blades by extreme pressure on the wheel.

With a good bottom it should not be required of the chromium to erase or cut out scars or scratches, as it must be understood that there can be no combination of any products which will cut severely and polish at the same time, and that chromium is no exception to this rule. However, very fine hair lines can be removed by the chromium and with the speed suggested, and the man at the buff can, if qualified, produce the high mirror-like finish on both steels. Or, on the other hand, he can turn out a dull gray finish which is due, without exception, to poor bottom or improper speed of buff at the final operation.

Chromium finished steel products have revolutionized the cutlery industry and have actually reduced the operation cost of producing a highly finished article. The mirror finished cutlery has certainly stimulated and increased consumer demand; for although the ultimate purchaser is not sufficiently expert in judging the general quality of steel but must rely upon the manufacturer's reputation or the seller's favorable comment, he is,

nevertheless, in the end the sole judge of the beautiful appearance of the same, which is the prime selling factor.—F. A. Zucker.

POLISHING WITH RECLAIMED ABRASIVE

The reclaiming process is comparatively inexpensive, the cost of the salvaged material working out at about one-fifth of the cost of the new. From tests carried out it has been proved that grain of good cutting quality, and in quantity large enough to pay for reclaiming, is deposited in the polishing hoods, the refuse from which, at most plants, is consigned to the rubbish heap. Of this reclaimed grain a considerable percentage has not even been reduced in size, having been dislodged from the glue bond before having been dulled or broken up by pressure against the article being polished, or thrown off by centrifugal force. Moreover, as a result of the breaking up that occurs, a supply of the smaller sized grain is provided that is suitable for the finer polishes, thus making it unnecessary at some plants to purchase any small sized grain at all. Below are given the results of a test of refuse grain:

	Lot A	Lot B	Lot C
Percentage of grain in total weight of refuse	51.6	36.5	63.18
Percentage of usable size grain in the reclaimed product	65.75	72.12	46.
Percentage of usable grain in total weight of refuse	33.93	26.32	29.06

These percentages of reclaimed unsable grain are sufficiently high to warrant reclaiming, always assuming, of course, that its cutting quality is satisfactory. It might be stated that lot *B* was from a plant which maintains a high standard of polishing wheel practice and considered reclaiming for that reason to be unprofitable in its case. One noteworthy fact was that, in all three cases, the largest size of grain used composed the major part of the usable grain. This was an important feature as, at the three plants from which the refuse was obtained, this size is by far the most used and figures prominently as a part of the polishing costs.

To obtain definite proof of the breaking-up action that occurs to the grain during polishing, and to ascertain what proportion of each size grain used was returned, another test was carried

POLISHING AND BUFFING

out. For this object the polishing wheel hoods were all cleaned out and the weight of each grain size used on the wheels recorded. The result is detailed below:

Size of grain	Weight of abrasive applied to wheels, pounds	Weight returned in reclaiming, pounds
No. 36	590.5	243.13
Intermediate .....	.....	111.05
No. 80	55.25	52.69
Intermediate .....	.....	42.44
No. 150	11.	21.16
Total	656.75	470.47

Roughly, half of the No. 36 size was returned, a quantity equal to the original of the No. 80, and double the original quantity of the No. 150. The difference, 186.28 pounds, 28 per cent of the original total weight, had disappeared. This doubtless was of a very fine size and had passed off in the reclaiming with the dirt in the wash or had adhered to the magnetic particles when going through the separator, or had been drawn off in the exhaust during polishing.

This comparison of the weights and sizes returned with what was put in points clearly to the conclusion that breaking up takes place, and consequently that grain with new cutting edges is produced. The percentage of the usable sizes returned is so high that it is decidedly poor business to consign it to the rubbish heap. It should also be kept in mind that the nonusable polishing sizes are still available for the various other uses to which abrasives can be adapted.

In another test, three different sets of wheels were made up. The first lot was coated with new abrasive, the second with mixed abrasive (75 per cent reclaimed and 25 per cent new) and the third with reclaimed abrasive. The final cost per unit polished is given below:

Material	Cost per unit
All new abrasive	\$0.129
Mixed abrasive	0.098
Reclaimed material	0.094

While the wheels made up of all reclaimed grain gave the lowest cost per unit it is obviously impossible to carry on with it,

a quantity of new grain having necessarily been added to make good the loss occasioned by the reduction of the grain to smaller sizes during polishing. For regular use, therefore, the advantage of reclaimed abrasive is clearly established.

The quantity of new abrasive required to be added will vary, but it has been found that when the new is a few sizes coarser than what is usually used 25 per cent to 30 per cent will be found sufficient to keep up the supply of the large size.

Regarding the time taken at the polishing operation the average for the three sets worked out almost exactly the same, thus demonstrating that the reclaimed abrasive had not perceptibly lost its cutting power. That the abrasive in a glue-bonded polishing wheel does not become dulled is most probably due to the fact that the glue is not sufficiently strong to hold the abrasive long enough to have the cutting edges worn down. The manufactured abrasive in general use stands at 9.5 on Moh's scale of hardness. It would, therefore, have to be presented to a metal surface being polished for an appreciable length of time to have its edges blunted. Even then only one side of the particle would be affected, and in the next set up another side would most likely have to do the work. Samples of reclaimed grain were microphotographed but neither the photographs nor examination of the grain under a microscope revealed rounded edges. The reclaiming process consists of three operations:

- 1.—Washing the refuse with hot water to liquify and draw off the glue, to carry off any fine floating dirt.

- 2.—Passing the dried-out refuse through a magnetic separator to remove all metallic substances to which also much fine dust adheres.

- 3.—Passing the abrasive over screens of a mesh to give the sizes of grain desired.

The equipment for washing and drying is a circular steel tank 4 feet 6 inches in diameter and 1 foot 4 inches deep. Inside this tank is a smaller one of 1 foot 10 inches in diameter with its walls concentric to the outer ones but 4 inches lower. The space between the walls of these two tanks is where the refuse is washed and dried. The dry refuse from the polishing hoods is shoveled into a depth of about six inches. Water and steam are then turned on, a temperature of about 150 degrees being necessary to liquify the glue. To keep the refuse thoroughly

broken up, eight shovels or paddles keep continuously revolving. These paddles are suspended from two arms, four paddles on each arm. The rate of movement is 16 revolutions per minute. The heating is obtained from a steam-heated compartment at the bottom of the tank. After about 45 minutes the glue comes to the surface, and the water, which had been turned off before overflowing into the central tank, is again turned on and the paddles stopped for about ten minutes to allow the solid matter to settle. The paddles are again set in motion and the small jet of water entering the tank keeps the glue overflowing into the central tank which has a direct connection with the sewer, a sump being provided for safety. With the water kept fairly hot a couple of hours will be enough to carry off the glue and dirt. The paddles are then stopped and the water drained off.

The mixture is then dried out. This is accomplished by keeping the paddles revolving and the steam turned on. The paddles are left running about an hour and then the steam is left on just enough to keep up the drying out process. This may be done overnight and in the morning another half hour's running of the paddles will have the mixture dry enough for the separator. The mixture, after being screened through a coarse mesh sieve to remove any bolts, nuts, washers, etc., is carried by chain buckets to the hopper of the magnetic separator. It then feeds gradually down into the separator on to a revolving disk off which a magnet attracts all the metallic particles to which much fine dust clings. Passing out of the separator the clean grain moves down a vibrating chute on to the screens where it gets sorted out into the desired sizes and finally deposited into the several containers.

The labor required at the washing, drying and screening is insignificant, shoveling the refuse into and out of the tank being the chief item. The rest is a matter of periodic visits to see that everything is running right, to turn a valve, or to empty a container. A man accustomed to the job is able to properly time his visits. Of the cost factors steam is the principal.

Believing that the grains of the reclaimed abrasive are left with a coating of fine filmy glue which prevents perfect bonding some firms have gone a step further in the reclaiming process. This is to put the abrasive through what might be called a roast-

ing operation which removes any glue that may have survived the washing. The result is a thoroughly cleaned abrasive.—John Alexander.

SELECTING BUFFING ABRASIVES

The condition of the surface to be finished must be considered in the selection of the buffing element. Deep scratches and pits cannot be removed with a material designed to produce a high finish. Tripoli compositions, which are cutting mediums, can be used on soft metals and emery cake on ferrous materials. The latter material also can be used on soft metals where the surface is in poor condition, demanding the removal of an excess amount of material. It is practicable always to use the finest grade of material that will remove blemishes with reasonable speed, it being borne in mind that the abrasive mediums leave scratches themselves. While these scratches cannot be seen with the naked eye they show up readily under the microscope. The depth of the scratches depends on the abrasive used and the condition of the metal. The character of the ultimate finish desired also is a factor to consider. When a high lustre is wanted a coloring or lime composition must be used. These products have practically little abrasive qualities so that the surface first must be prepared with fine emery, tripoli or crocus. No one product can produce a fine finish and cut fast at the same time. On some products No. 140 emery cake will result in a satisfactory finish. On another product where a different finish is wanted, No. 140 emery cake might be used for the first operation of cutting down to be followed by processes with finer materials.

When the work is to be nickel plated it must be remembered that the nickel deposit will not fill up scratches—it goes into them instead. Thus the work must be smooth before it is plated. As the average thickness of nickel plate is generally not over 0.0005-inch, it is seen that no buffing can be done to remove scratches as the entire nickel surface would be cut through.

SELECTING BUFFING WHEELS

Many experienced buffers assert that it is preferable to have a buff with a closely woven fabric consisting of strong and tightly twisted fibers. In the case of buffs which closely re-

semble each other, it sometimes will be found that there is a wide difference in quality. In making the decision, which of two buffs to buy, attention should be given to the quality of the fabric of both, as a buff will be useful in proportion to the amount of long, hard-twisted fibers in the cloth. Their comparative value may be ascertained by examining the fabrics under a magnifying glass, counting the number of threads to the inch, taking into account the size of the individual threads and their distance from one another.

The amount of starch and gum with which the cloth is loaded also should be estimated. This can be done without a chemical test and will be revealed by examining the buff closely under a magnifying glass. Some of the fibers of each sample then should be unraveled and their relative strength tested and compared. If a sample of cloth is heavily loaded, or if the threads of the fabric have short and weak fibers, the buff is of inferior quality.

A buff should stand out straight from the axis of the buffing lathe spindle and it should be circular and evenly balanced. Trueness of diameter and accuracy of balance are essential to the best work. Fullness of weight, uniformity of material and fullness of the count of disks are decidedly important.

Buffers should be selected carefully for the kind of work they are to perform. Some buff manufacturers purchase special grade of goods from different mills for various purposes. For some grades of work the output of one mill may be superior to that of another, and the purchaser should recognize this in making his selections. Buffs also can be made to order to suit the ideas of the buyer.

When ordering buffs of any kind, the buyer should furnish the following specifications:

Type of buff, whether full disk, sewed piece, etc.

Diameter of buff.

Grade of cloth. In sewed-piece buffs, the order should state whether hard fancy, soft fancy, bleached, or unbleached material is wanted.

Diameter of arbor hole.

Standard or special sewing. If special, details should be given.

Number of ply when loose buffs are required.

When ordering small diameter buffs, sometimes made of

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whole-piece sections, with raised, or hardened centers for straight, or tapered spindles, the following information should be given:

Type of buff, diameter, whether machine or hand-sewed, diameter of arbor hole and whether tapered, or straight spindle.

White-bleached, pieces, stitched buffs, constructed of new, unwashed material free from loading of any kind or unbleached pieced, stitched buffs, of the same kind of material are especially suitable for finishing stove work. Soft fancy-piece buffs are used for finishing chandeliers, shell and similar work where a softer buff than the two foregoing is desirable. Hard fancy-piece buffs are particularly useful for finishing plumbers' supplies, brass goods and wherever a hard, stiff buff is needed. The following are approximate weights of pieced buffs in the different diameters which have been adopted as standard.

Diameter, inches	Weight per section, ounces
8	6
9	8
10	10
12	12
13	14
14	16
15	18
16	20
18	26

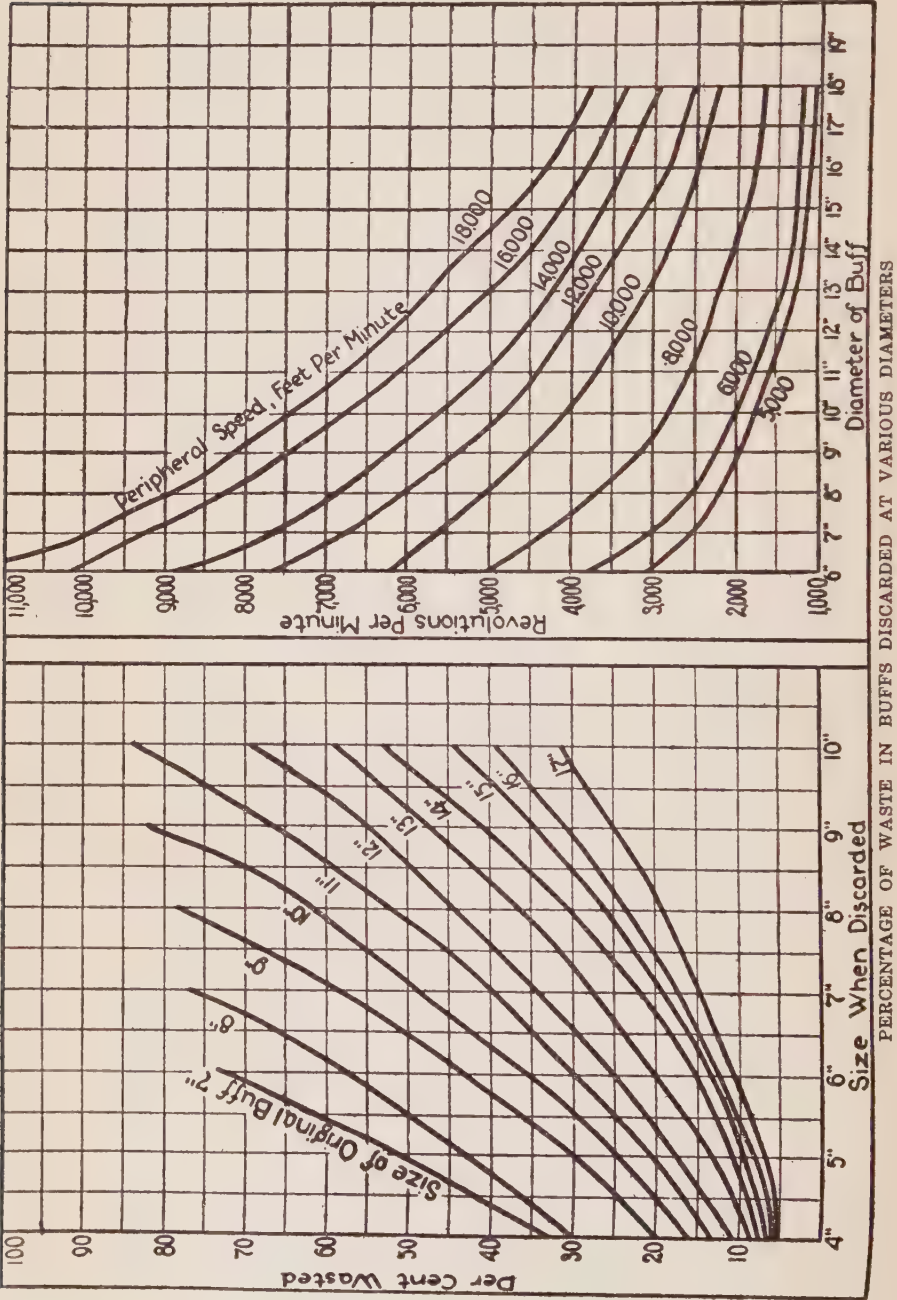
Open, or loose full-disk buffs made of unbleached muslin sheeting of a grade affording a hard cutting edge with considerable flexibility are used extensively for finishing large, heavy brass and copper surfaces and in the manufacture of sound reproducing machine horns, bedsteads, skates, toys, bells and many other articles for which an extremely hard-face cutting buff is desirable. Sometimes buyers prefer to have sections of the wheel glued together in place of piece buff sections. Such buffs come in sizes from 3 inches to 24 inches in diameter and variously from 18 to 40-ply, either sewed once at the arbor hole, or spirally.

A slighter weight buff of practically the same type as the foregoing is used for fast cutting on automobile lamps, reflectors and other metal parts where the buff works on the inside of the object. It is a little more flexible than the one previously described, having a very close weave and wears down without tearing the threads.

An unbleached muslin buff with sufficient threads to produce a good cutting edge and made in a small size is well adapted for coloring on medium and light work. Another type, usually a loose disk buff made of similar material, has every two layers turned to cross the threads, thereby preventing the buff from wearing flat. Another kind of buff used for coloring work and also for putting a high finish on celluloid surfaces is made of particularly heavy unbleached sheeting. Each strand is heavy and thick, causing the buff to open and thereby producing a soft edge. For finishing steel parts, small hardware specialties, sewing machine parts, lineman's tools and small tools such as pliers, a buff made of hard bleached muslin can be used. They are put through a special bleaching and finishing process, so that each thread is stiffened.

Hand-sewed, quilted muslin buffs made from unbleached material of various grades, are employed in cases where the speed will not be sufficiently great to make the buff stand out straight from its axis without the aid of stitching. Such buffs are desirable for the jewelry trade, cane and umbrella manufacturers, makers of metal novelties, pipe manufacturers, manufacturers of syphon tops and similar ware and they are also useful in tortoise shell and celluloid work. Canton flannel buffs, hand and machine sewed, made up of the softest grade of materials are supplied for jewelers, goldsmiths and silversmiths. These are used for high coloring work on precious metals and on hard rubber and in other industries where a buff is desired that will not scratch or mar the work.

For doing celluloid and coloring work, woolen cloth buffs often are desirable. They are constructed of particularly heavy, all-wool cloth and produce a high color, as each strand is heavy and thick, allowing the buff to open thereby providing an extremely soft edge. Hard canvas wheels for roughing-out purposes are made of layers of extra heavy canvas cemented together without stitching, their faces, while hard, having considerable resiliency. Suitable for nearly all uses where a canvas wheel can be employed, are wheels made of layers of duck cloth, or denim, in single sections, about 3/16-inch thick, compactly sewed with stitches 3/8-inch apart and cemented together under pressure to the desired thickness, with a canvas cover cemented



to the outside. This makes a tough, flexible buff, whose face can be set-up with glue and abrasive.

Wheels also are made of hard-finished white cloth in single sections about 3/16-inch thick, with rows of stitching, 1/4-inch apart. The sections are cemented together under pressure to the desired thickness. The resulting wheel is extremely hard and is suitable for cutting down brass with tripoli, or it can be set up with glue and abrasive for polishing purposes.

Sewed canvas wheels are favored when a wheel is desired that is somewhat harder than the ordinary sewed wheel, but not quite so hard as a glued wheel. When set-up with glue and abrasive, the sewed canvas wheel is effective for roughing-out purposes. The wheel is formed by cementing together a number of 1/2-inch sections, until the desired thickness is obtained. Each section is made up of a number of pieces of canvas with whole disks on the outside firmly held together by spiral stitches from the arbor hole to the periphery, the rows being 3/8-inch apart.

A buff cuts best when it is being operated at a speed that makes it stand out stiffly. The greater the diameter, the greater will be the number of feet of surface which passes the work in a minute at a given speed. As a buff wears down, it naturally becomes smaller and the number of feet passing the work per minute, of course, is correspondingly reduced. Cutting down buffs should be run from 9000 to 15,000 feet peripheral speed per minute, with 12,000 feet as a fair average. Coloring buffs should be operated at 5000 to 8000 feet per minute.

The accompanying charts show the percentage of waste in buffs discarded at various diameters and operating speeds for various size buffs. The chart at the left gives the percentage of waste of buffs that are discarded at various sizes. For example, suppose a buff is 12 inches in diameter and that it is discarded when it has been worn down to a diameter of 8 inches. Taking the 12-inch curve and noting where it intersects the 8-inch line, then following horizontally to the left, it will be noted that 45 per cent of the original buff is wasted. Similarly, if a 12-inch buff were discarded when reduced to a diameter of 6 inches, 25 per cent would be wasted.

The chart at the right shows at what speed any size

buff must be run to impart a predetermined peripheral speed. For example, let it be assumed that a 14-inch buff must be run at a surface speed of 8000 feet per minute. The vertical line marked 14 inches is followed up until it crosses the 8000 feet per minute curve. At that point an imaginary line is extended to the left at right angles to the buff diameter line. This line would cross the extreme left of the chart slightly above the 2000 revolutions per minute line, giving an approximate speed of 2200 revolutions per minute.

SETTING UP POLISHING WHEELS

Abrasive grain for use in setting up polishing wheels usually is supplied in the following sizes: 8, 10, 12, 14, 16, 20, 24, 30, 36, 46, 54, 60, 70, 80, 90, 100, 120, 150, 180, F, FF and FFF. A keg of abrasive grain generally contains 325 pounds, a half keg 170 pounds, while lesser quantities from 100 pounds downward are packed in bags.

Polishing wheels cannot be used efficiently unless they are set up with the proper abrasive, held in place with the right kind of glue. If the glue is not of just the right grade it is probable the results will be such that both the abrasive and the polishing wheel will receive the blame for inefficient work which justly belongs to the glue. For that reason a careful study has been made of glue for various polishing wheels.

There are three kinds of glue manufactured from as many animal products, but only one kind will give the polisher satisfactory service. Such glue holds the abrasive to the wheel until the grains had finished their work, or until their cutting qualities are gone. It is just as necessary to have glue used properly as it is to have the quality first in the raw material. If it is flake glue, or in flat pieces, it should be soaked from one to 12 hours in cold water. Hot water produces a scalding effect which always is detrimental.

The exact time of soaking depends upon the thickness and grade of the glue and the user must determine this by experience. Ground glue will soak in five or 10 minutes, and you can dissolve more in the melted glue that is already in the pot in say, two minutes. To get the best results, prepare and cook ahead just what is needed and use as fresh as possible. Pro-

longed cooking injures the strength of the glue. Glue will not hold unless the materials to be glued are put together while the glue on them is still hot and liquid. This detail must not be overlooked.

Many complaints experienced in the glue business may be accounted for by the fact that wheels were not set up properly. When first setting up a wheel, the glue should be thoroughly rubbed into the surface with a brush, much in the same manner as a barber works lather into the beard in shaving. In this manner the glue is worked into the polishing wheel thoroughly.

Then the glue should be allowed to dry, possibly over night. After this drying out process the wheel should be again coated with glue, this time, much in the same manner as a painter would apply a coat of paint, being careful to leave no laps, for if the wheel in this latter process be given an uneven coat, it results in ridges which, as soon as the work is held against the wheel, causes the abrasive to fall off in pieces. After the wheel is thus coated with glue, it is rolled in the abrasive trough.

Another cause of abrasive not sticking to the wheel is that some polishers after working the wheel down to such an extent that it requires a new coat, soak it in water to remove what remains of the old coat. These wheels are then dried out before recoating. If the wheels are not thoroughly dried there is not a good foundation upon which to recoat, and while the outer surface would show the proper finish, as soon as the work is held to the wheel, the abrasive breaks away, thus causing the complaint of inferior glue.

Glue should never be allowed to boil, and it should not be heated 150 degrees Fahr. The lower the point at which the melting takes place, the better. Unless you have a thermometer you have to guess at the temperature and if you guess wrong and your glue becomes overheated, then its strength is gone. Never attempt to melt glue by turning live steam directly into it.

Steam in direct contact with glue is very injurious. Never allow a scum or crust to form on the top of the glue pot. That means wasted glue. Warmed over glue is usually worthless. There should be just enough glue prepared at one time to last that day and no more. Glue that is permitted to stand loses its strength rapidly.—Frederic B. Stevens.

SILVERWARE POLISHING METHODS

Articles of silver are polished in a similar way to brass works, except that soft leather wheels are used for roughing and soft buffs for finishing. After the articles have been cut down they are finished on a soft muslin buff with crocus composition then. They are then cleaned and plated with a very light coat of silver. This is called the "strike." They are then cleaned, first in cold and then in hot water, dried in sawdust, and finished on a flannel buff with a little fine rouge made into a paste with alcohol or water. After this polishing the article should be washed in soap and water, dried and finally buffed with dry rouge, which will give the article a beautiful appearance.

Solid silver after leaving the silversmith is either cut down with bull-neck wheels about 6 inches in diameter, or on soft felt wheels. Where work with a raised pattern will not permit of the use of a wheel, circular bristle brushes are used. The work then is buffed on a muslin wheel with crocus composition and then it is finished on a canton flannel wheel.

Silver articles such as match boxes, cigarette cases, toilet ware, brooches and other small articles, are polished as previously described, but leather and felt wheels of various shapes and sizes are used according to the shape of the various articles.

Spoon and fork work from the rough stampings, are first edged on solid wheels; very narrow ones being used to get between the prong or tines. The stampings then are finished with very small leather or felt wheels, set up with emery, followed up with tripoli, and finally with rouge. The finer the work is finished before plating, the less polishing will be required after plating; thus leaving the deposit of silver heavier on the finished articles.

Jewelry coming in so many different forms and shapes makes it the most difficult of all polishing work. This is due to its small and delicate construction. The pieces are polished in many instances in a similar manner to silverware, but with different materials. Circular bristle brushes are largely employed for polishing jewelry. The article is first brushed with a circular brush with crocus powder mixed with oil, it is then washed out in a hot solution of water and washing soda, dried out in boxwood sawdust and then finished on a buff or very

fine brush with rouge. All the wheels used in polishing jewelry are very small; ranging from one to six inches in diameter.

A large quantity of very fine jewelry, owing to its delicate construction and also to the fact of its having stones set in place, is usually polished by hand. This is done with the same materials but various sticks and polishing threads are used in doing this as the buffs on the lathe would be too severe on the work. The polishing lathes used for jewelry are of a much lighter type and all have the motor in the head.

Polishing barrels are greatly in demand where large quantities of work are required to be done cheaply and quickly.

The polishing is done by the continued friction of one article against another in connection with the various ingredients put in the barrel to cut, grind, or polish as required. In this method of polishing care must be taken that the articles in the barrel are not thrown, but rolled against each other with a slow easy motion. Therefore the barrel must be run slowly. Under no circumstance should the barrel revolve at such a speed as to carry the work round with it, the barrel should be filled to about three-fifths of its capacity. In large factories where a lot of work is put through, separate barrels are used for finishing.

Scratch brushes come in many sizes but for the finishing of jewelry they range in size from about three to six inches, it should be clearly understood that brushes of small diameter and fine wire should be run at a greater speed than those of a larger diameter. Scratch brushing is done on a separate lathe covered by a box as the brushes run under a stream of water, the speed at which they run should be 800 to 1000 revolutions a minute. This speed varies according to the thickness of the wire in the brush, the finer the wire the greater the speed and the coarser the wire the slower the speed.

For brushing silver plated articles, brushes of varied shapes are made for the different parts such as thimbles, cigarette cases, match holders, etc., also for the insides of coffee pots and water pitchers. The solution employed for scratch brushing used to be stale beer, but now as that is a thing of the past, the solution is made by dissolving $\frac{1}{2}$ pound of double white sizing in two gallons of water. When the solution is made it is poured into a can at the top of the box on the lathe, allowed to drip

slowly on the scratch brush, about a gallon of the solution should be allowed to run through every fifteen minutes. The flow of the solution is regulated by a cock and great care should be used to see that the solution drops between the brush and the articles and not upon the top of the brush. The article should be brushed till it is perfectly bright and then rinsed in hot water and dried out in boxwood sawdust.

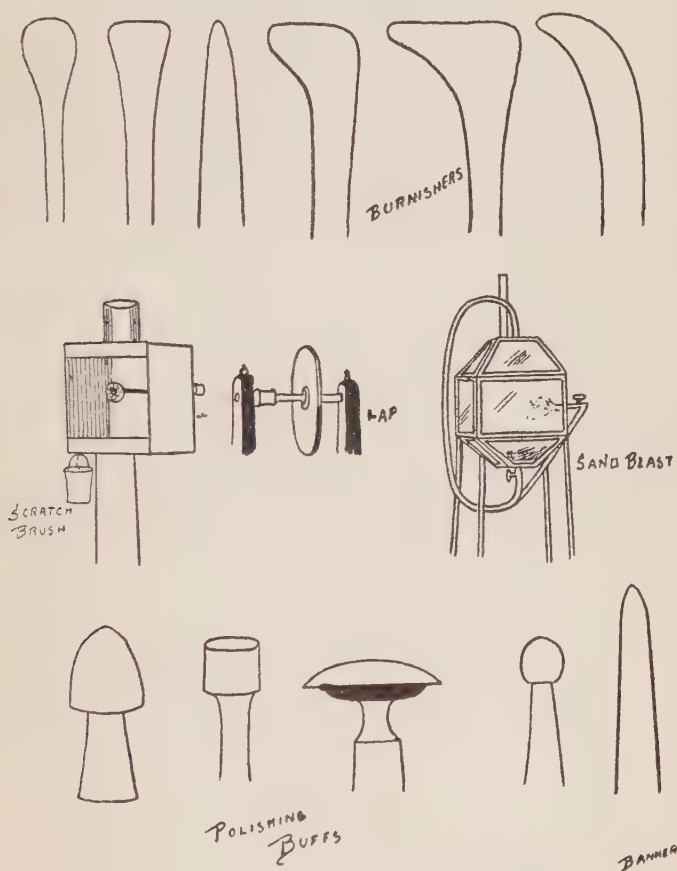
A bucket is placed under the scratch brush to catch the liquid which may be used over and over again, this solution may be strained between times to get it free from dirt and it will then be found to work much better the older it gets. In making up this solution see that the sizing is thoroughly dissolved or else the resulting work will be faulty. In all scratch brushing see that the brushes run at the right speed and if the brush is of heavy wire do not run it too fast or it is liable to break. The stocks of small brushes should be filled with molten lead. This holds them together.

After a gold or silver article is perfectly dry and well wiped, burnishing is the last thing to be done and is carried out in the following manner: The materials used are burnishers made both of steel and agate, also bloodstone. With these are used soap and water, a polishing buff and putty powder. A steel burnisher is moved backward and forward over the article which must be kept well moistened with the soap and water. The shape of the burnisher depends upon the article being burnished. After the article has been rubbed all over with the steel burnisher a bloodstone burnisher is next used for finishing the work. This gives the final brilliance so much to be desired in fine work.

All burnishers must be kept bright, and to do this they are polished on a piece of hardwood such as oak, finally finishing by rubbing on a buff stick covered with buff leather and putty powder. After the article has been burnished the soap must be washed off in hot water and finally dried in sawdust. In some cases the article after being burnished with the steel burnisher is finished by buffing on the lathe with a fine cotton buff and rouge. To make the soap paste, dissolve four ounces of best yellow soap in $\frac{1}{2}$ pint of hot water. The water must be kept hot and stirred until the soap is dissolved.

POLISHING AND BUFFING

All articles such as cigar and cigarette cases, clock dials, etc., that have a sand finish are done in a sandblast apparatus which blows a fine stream of sand over the article. Owing to its abrasive nature the sand cuts into the metal, leaving it with a very fine mat surface or finish. Different grades of sand may



TOOLS FOR FINISHING SILVERWARE AND JEWELRY

be used for different finishes. The sand should be carefully screened before using to remove impurities.

Lapping is done on a revolving disk. Some are made of metal and some of hard wood or felt. The lap must run perfectly true; much more so than a buff, as it is on this smooth

running that the success of the work depends. To get this smooth running, the lap usually is turned up on the spindle on which it is run. Fine emery is used to do this work.—George A. Banner.

STRAP POLISHER

This device embodies a belt set up with abrasive which runs over two flanged pulleys. One pulley is the driver, the other the idler. It is used for polishing flat surfaces. In this respect it differs from the belt grinder, as such a machine is used more for removing metal than it is for polishing. Strap polishers usually are operated in conjunction with a polishing lathe, the driving pulley being mounted in place of a polishing wheel. A rest is provided under the belt so that the work can be held level.

TALLOW STICK

A material used for lubricating set-up emery wheels for finishing or oiling operations. The material is molded in a cardboard container, like a mailing tube, and usually it contains other ingredients besides tallow which prevent undue softening in hot weather. Tallow sticks weigh about one pound each.

SECTION XIV

SAFE OPERATION OF WHEELS

The day has passed when a grinding wheel was considered an unsafe tool to operate. Years ago, when the art of wheel manufacturing was not on the high plane it enjoys today and when wheels generally were operated without guards of any kind, accidents caused by grinding wheel fractures were of common occurrence. The subject of grinding wheel failures has been given much thought and attention during the past decade and sensible rules have been formulated for their safe use. Data in this section is arranged under the following heads:

	Page		Page
Applying Work	529	Safety Code	520
Breakage of Grinding Wheels.....	518	Side Grinding	529
Dresser Guards	529	Spindle Lubrication	529
Inspection After Breakage	528	Starting New Wheels	528
Protection of Cup Wheels.....	521	Types of Protection Devices	525
Protection of Cylinder Wheels.....	521	Wet Grinding Wheels	529
Protection of Ring Wheels.....	521	Wheel-Flange Specifications	526
Protection Hoods	521	Wheel-Operating Rules	528
Replacing of Hoods	528	Wheel Truing	529
Responsibility for Wheels in Use	528	Work Rests	530

SAFE OPERATION OF WHEELS

BREAKAGE OF GRINDING WHEELS

Grinding wheel failures are not common occurrences when the large number in daily use is considered. However, when a wheel breaks the trouble can be traced to a number of general causes.

1—The wheel may have been cracked in shipment. It always is a good plan to let a new wheel run for a few minutes before applying the work. Thus if a fracture is present, the centrifugal force generally is sufficient to cause the wheel to burst.

2—If the lead bushing fits the spindle too snugly this may cause the wheel to break. Lead expands rapidly under heat and thus as the spindle heats the lead bushing expands, bringing a tremendous strain on the wheel. This, together with the centrifugal force to which the wheel is subjected, may be sufficient to cause a fracture. When mounting a new wheel it should fit over the spindle freely, about 0.002-inch being considered a safe clearance. If the wheel fits too tight, the bushing hole can be enlarged readily with a bearing scraper or a pocket knife.

3—If the work rest is not adjusted close to the wheel the work may become wedged and this is almost certain to cause the wheel to break. The rest should be kept adjusted to within $1/32$ inch of the wheel face at all times.

4—Work never should be applied forcibly to a cold wheel during the winter months. This applies to wheels used in cold cleaning rooms and also to wheels taken out of a cold room before mounting. The work should be applied with slight pressure only until the wheel has had a chance to warm. Otherwise the unequal expansion in the wheel will cause it to break.

5—Sudden blows and side strains frequently cause wheels to fracture. Thus care should be exercised to see that the

wheel is not subjected to these undue stresses. Grinding on the side of a comparatively thin wheel is to be discouraged. Where side grinding is necessary, cup or cylinder wheels should be used. Thin wheels should be in elastic bonds (shellac or rubber), as the vitrified and silicate bonds will not withstand undue side strain. The latter wheels are not flexible.

6—If the wheel is out of balance an undue strain is developed that may cause a fracture. If an out-of-balance wheel cannot be brought into balance by dressing, it should be removed from the grinding stand, as such a wheel is a menace.

7—The wheel flanges must be of equal diameter, recessed at the back and they should conform to standard dimensions. If one of the flanges is larger than the other, an undue side strain is set up when the spindle nut is tightened. Compressible washers of leather, rubber or blotting paper should be interposed between the wheel and its flanges. The spindle nut should be set up just tight enough to hold the wheel. If abnormal pressure is used, the wheel is subjected to an unnecessary crushing strain.

8—If the spindle of the grinding stand designed to accommodate two wheels is removed, care must be exercised in putting it back. Standing in front of the machine, the end of the spindle at the right should carry the right-hand thread; that at the left the left-hand thread. In this location the action of the work on the wheel tends to cause it to tighten the nuts. If the spindle is mounted in the reverse direction the grinding action will tend to loosen the nuts.

9—Never under any condition should a grinding wheel be operated at a speed greater than that recommended by the manufacturer. Grinding wheel tags always give the correct operating speed and these data should be followed strictly. Over-speeded wheels are liable to burst.

The following causes of grinding wheel accidents were compiled by the American Emery Wheel Works:

THE ABRASIVE HANDBOOK

Cracked wheel (caused by)	{	Rough handling in transportation Dropping or striking against some object while not being operated ...	{	During storage While being mounted While standing
		Being forced on improper sized spindle.....	{	Too small bushing Too large spindle
		Heated spindle.....	Tight bearings	
		Only one flange, nut against wheel	{	Bent or broken flange Bushings projecting beyond sides of wheels
		Uneven bearing of flanges.....		High spots on flanges High spots on wheels
		Flanges of different diameters Flanges not properly relieved Fault of compressible washers.....	{	Missing Too thin Too small diameter
Too high rim speed (caused by).....	{	Tightening of nut too hard Hacking of wheel Screwing wheel on taper arbor		
		Spindle overspeeded.....	{	Overspeed when first set up Speed increased—Desire for increased cutting Use of cone pulley—Shifting to small pulley
		Use of too large wheel for spindle speed.....	{	Wheel initially too large Too large wheel substituted Wheel of different grain, and lower recommended speed substituted Wheel of different shape substituted Wet wheel substituted
Catching work between rest and wheel (caused by).....	{	Improper adjustment of rest		
		Improper handling of work.....	{	Side grinding when rest not designed for it Pushing work under rest
Out of true (caused by)....	{	Loose bearings Bent spindle Loose frame Rough or improper use		
Unbalanced wheel (caused by).....	{	Wheel standing in water Side grinding Wheel untrue		
Weakened wheel (caused by).....	{	Side grinding Hacking wheel		
Too small spindle (caused by).....	{	Wheel spindle used for size of wheel		
Side grinding on improper wheel (caused by).....	{	Lack of proper equipment Inexperience of men		

SAFETY CODE

The Safety Code for the Use, Care and Protection of Abrasive Wheels is a 28-page illustrated booklet which will be supplied gratis by any prominent grinding wheel manufacturer. On April 3, 1920, the American Engineering Standards committee invited the International Association of Industrial Accident Boards and Commissions and the Grinding Wheel Manufacturers' Association of the United States and Canada to act as joint sponsors for compiling the code in question. Subse-

SAFE OPERATION OF WHEELS

quently the code was drafted and approved by the American Engineering Standards committee. The remaining data in this section were abstracted from the Safety Code.

PROTECTION OF CUP, CYLINDER AND SECTIONAL RING WHEELS

Cup wheels, cylinders and sectional ring wheels should be protected with hoods, enclosed in protection chucks or girdled with protection bands. Not more than $\frac{1}{4}$ -inch of the wheel should project beyond the protection. However, if the rim of the wheel is less than two inches thick the wheel may be permitted to protrude one inch beyond the protection. If the wheel is more than two inches thick at the rim it may safely protrude two inches beyond the protection. This limit, however, should not be exceeded. If protection hoods are employed they should conform to standard specifications. In cases where the chuck that holds the wheel is the sole means of protection, the chuck should be designed so that the jaws at all times will protect the wheel up to the points previously specified. Protection bands should conform to the following specifications:

They should be made of wrought iron or steel plate, or other material of equal strength. They should be continuous and bent to conform to the wheel contour. The ends should be riveted, bolted or welded together in such a manner to leave the inside of the band free of projections. The thickness of the bands should be in accordance with the following data, which is recommended by the American Engineering Standards Committee. These data show the size and spacing of rivets for riveted joints. If bolting or welding is used, the strength of the connections should be equal to that of the riveted joints shown in the table.

Size of Wheel in Inches	Thickness of Band in Inches	Minimum Diameter of Rivets in Inches	Maximum Distance Between Centers in Inches
Under 8	$\frac{1}{8}$	$\frac{3}{8}$	$\frac{3}{4}$
8 to 24	$\frac{1}{8}$	$\frac{1}{4}$	1
25 to 30	$\frac{1}{4}$	$\frac{3}{8}$	$1\frac{1}{4}$

PROTECTION HOODS

Whenever practicable, grinding wheels should be protected with adequate guards. In nearly every grinding operation a wheel guard can be used without inconvenience, one possible

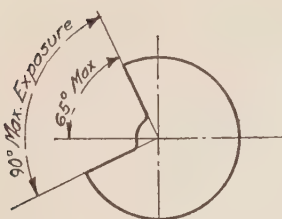


FIG. 1

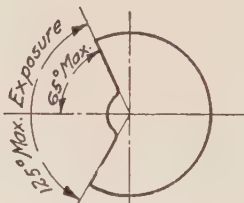


FIG. 2



FIG. 3

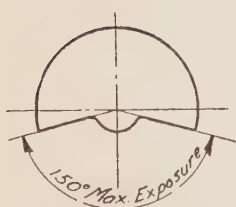


FIG. 4

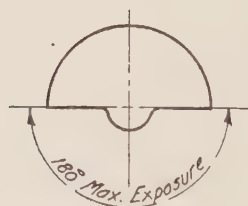


FIG. 5

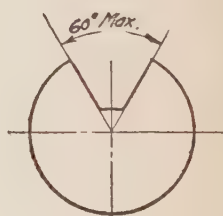


FIG. 6

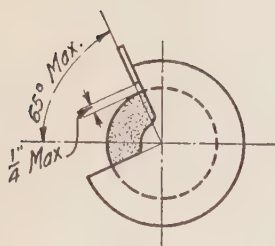


FIG. 7

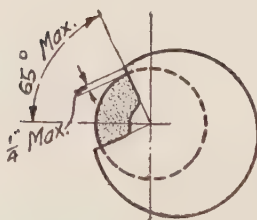


FIG. 8

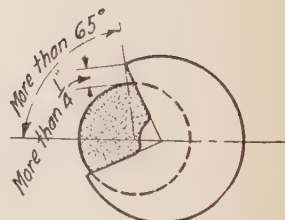


FIG. 9

FIGS. 1 TO 9—VARIOUS TYPES OF APPROVED PROTECTION HOODS

SAFE OPERATION OF WHEELS

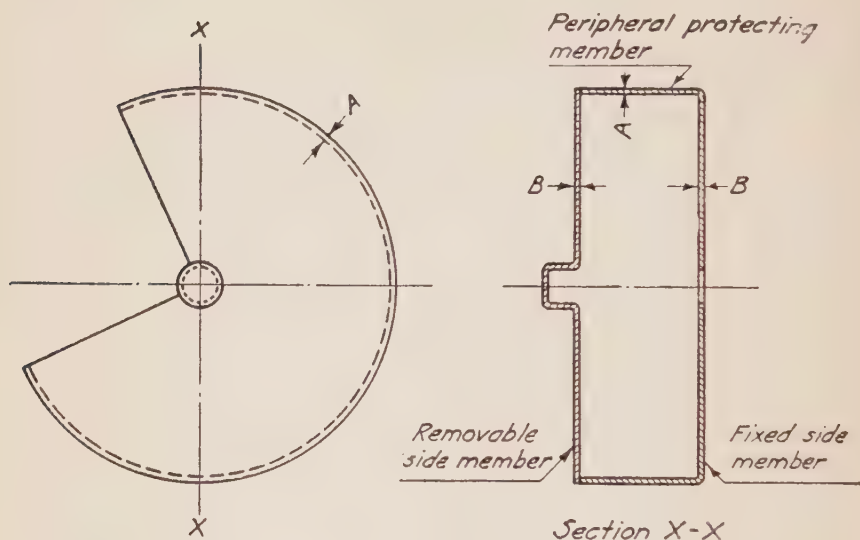
exception perhaps being that of sharpening milling cutters. Protection hoods should be mounted so as to maintain correct alignment with the wheels. However, if protection bands, safety flanges of wheel holding chucks are used, wheel guards are not necessary. The amount of exposure of the wheel face depends on the nature of the work. On bench and four stands the maximum angular exposure as shown in Fig 1 should not exceed 90 degrees or one-fourth of the periphery. This exposure should begin at a point not more than 65 degrees above the horizontal plane of the wheel spindle as the illustration shows.

In some instances the nature of the work requires contact with the wheel below the center line of the spindle. In this event the exposure should not exceed 125 degrees as shown in Fig. 2. This exposure should begin at a point not more than 65 degrees above and extend to a point not more than 60 degrees below the center line of the wheel spindle as the illustration shows.

The maximum exposure for wheels on cylindrical grinding machines should not exceed 180 degrees as shown in Fig. 3. This exposure should begin at a point not more than 65 degrees above the center line of the spindle. The maximum exposure for wheels used on surface grinding machines should not exceed 150 degrees as shown on Fig. 4. On swing-frame machines, the maximum angular exposure should not exceed 180 degrees as shown in Fig. 5. This also applies to portable grinders. The top of the wheel must be guarded at all times.

When it is necessary to grind on the top of the wheel the exposure should not exceed 60 degrees as shown in Fig. 6. Protection hoods should be constructed so that the peripheral protection member can be adjusted to the constantly decreasing diameter of the wheel as it wears away. An adjustable tongue, or its equivalent, can be used so that the foregoing specifications can be complied with. The maximum distance between the tongue and the wheel periphery or between the wheel periphery and the guard body should not be greater than $\frac{1}{4}$ -inch. In Fig. 7 a correct method is shown as an adjustable tongue gives the required angular protection for all sizes of wheels used.

Another correct example is shown in Fig. 8. In this case the hood is movable and it has an opening small enough to



Material Used in Construction Guard		Max. Thick. of Grinding Wheel	GRINDING WHEEL GROUPS BY DIAMETERS															
			3 to 6"		7 to 12"		13 to 16"		17 to 20"		21 to 24"		25 to 30"		31 to 48"			
			A	B	A	B	A	B	A	B	A	B	A	B	A	B		
Cast Members	Cast Iron	2"	1/4	1/4	3/8	5/16	1/2	3/8	5/8	1/2	7/8	5/8	1	3/4	1 1/4	1		
		4"	5/16	5/16	3/8	5/16	1/2	3/8	3/4	5/8	1	5/8	1 1/8	3/4	1 3/8	1		
		6"	3/8	5/16	1/2	7/16	5/8	1 1/2	1	5/8	1 1/8	3/4	1 1/4	7/8	1 1/2	1 1/8		
	Malleable Iron	2"	1/4	1/4	3/8	5/16	1/2	3/8	5/8	1/2	3/4	5/8	7/8	3/4	1	7/8		
		4"	5/16	5/16	3/8	5/16	1/2	3/8	5/8	1/2	3/4	5/8	7/8	3/4	1 1/8	7/8		
		6"	3/8	5/16	1/2	7/16	5/8	1 1/2	3/4	5/8	1 1/8	3/4	1 1/4	7/8	1 1/8	7/8		
Steel Castings	2"	1/4	1/4	1/4	1/4	3/8	3/8	1 1/2	7/16	5/8	1/2	3/4	5/8	7/8	3/4			
	4"	1/4	1/4	1/4	1/4	3/8	3/8	1 1/2	7/16	5/8	1/2	3/4	5/8	1	3/4			
	6"	3/8	1/4	3/8	1/4	1/2	3/8	5/8	1/2	3/4	5/8	7/8	3/4	1 1/8	3/4			
Fabric Members	Structural Steel	2"	1/8	3/16	1/8	3/16	1/4	3/16	1/4	1/4	5/16	1/4	3/8	5/16	1/2	3/8		
		4"	1/8	3/16	1/8	3/16	1/4	3/16	1/4	1/4	5/16	1/4	3/8	5/16	1 1/2	3/8		
		6"	3/16	1/16	1/4	1/8	1/4	3/16	3/8	1/4	3/8	1/4	7/16	5/16	5/8	3/8		
	Wrought Iron	2"	1/8	3/16	1/8	1/4	3/16	5/16	1/4	3/8	1/4	7/16	5/16	1/2	3/8	3/8		
		4"	1/8	3/16	1/8	1/4	3/16	5/16	1/4	3/8	1/4	7/16	5/16	1 1/2	3/8	3/8		
		6"	3/16	1/16	1/4	1/8	1/4	3/16	3/8	1/4	3/8	1/4	7/16	5/16	1 1/2	3/8		

FIG. 10—APPROVED MINIMUM DIMENSIONS FOR THE PERIPHERAL AND SIDE DIMENSIONS OF PROTECTION HOODS

give the required protection for the smallest size of wheel used. An incorrect example is shown in Fig. 9. In this case the hood is movable with the opening size correct for large wheels, but too large for the smaller wheels. A hood should be constructed so that it is not necessary when changing wheels to detach the peripheral protecting member from the side member which is connected to the machine. The hood should enclose the wheel, spindle end and nut and flange projections if any are present. With cylindrical grinding machines, however, in all operations where the work provides a suitable measure of protection to the operator, the hood may be so constructed that the spindle end, nut and flanges are exposed. Where the nature of the work covers the entire side of the wheel, the side covers of the guard can be omitted. Fig. 10 gives approved minimum dimensions for the peripheral and side members of protection hoods. Materials to be used in the construction of hoods must conform to and be in accordance with the following designated specifications of the American Society for Testing Materials:

Gray iron castings, A 48.

Malleable iron castings, A 47.

Steel castings, A 27, class A.

Structural steel plate, A 9, excluding specifications for rivet steel.

Wrought iron plate, A 42, class A.

TYPES OF PROTECTION DEVICES

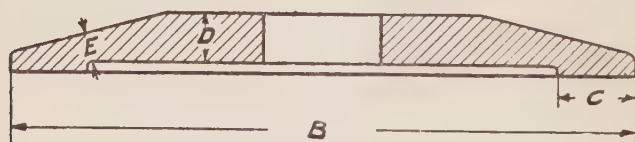
Grinding wheels should be provided with one of the following forms of protection, according to the American Engineering Standards Committee:

- 1—Protection hoods
- 2—Protection flanges
- 3—Protection bands
- 4—Protection chucks

These requirements, however, do not apply to wheels used for internal grinding operations or to wheels three inches in diameter and less running at a surface speed not to exceed 3,000 feet per minute. The forms of protection are listed in their order of preference. Forms 3 and 4 apply to cup, cylinder and sectional ring wheels and forms 1 and 2 to other shapes of wheels.

WHEEL-FLANGE SPECIFICATIONS

According to the American Engineering Standards Committee, all grinding wheels with the exception of those which are mounted in chucks should be operated between flanges. All taper flanges over 10 inches in diameter should be made of steel or of other material of equal strength. Other flanges may be cast iron or other material of equal strength. Flanges should be finished all over and they should be balanced. This require-

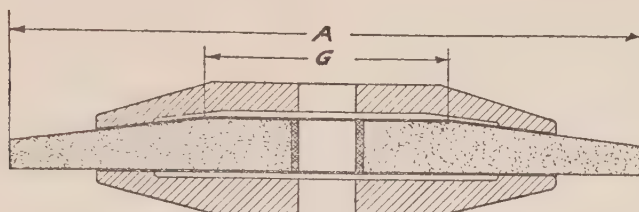


ALL DIMENSIONS IN INCHES

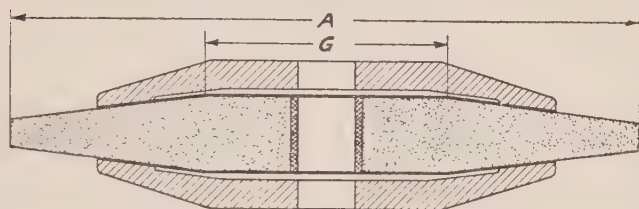
A Diameter of Wheel in Inches	B Minimum Outside Diameter of Flanges	C Radial Width of Bearing Surface		D Minimum Thickness of Flange at Bore	E Minimum Thickness of Flange at Edge of Recess
		Minimum	Maximum		
1	$\frac{3}{8}$	$\frac{1}{16}$	$\frac{1}{8}$	$\frac{1}{16}$	$\frac{1}{16}$
2	$\frac{3}{4}$	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{8}$	$\frac{3}{16}$
3	1	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{3}{16}$	$\frac{3}{16}$
4	$1\frac{1}{4}$	$\frac{3}{16}$	$\frac{3}{8}$	$\frac{3}{16}$	$\frac{1}{8}$
5	$1\frac{1}{2}$	$\frac{3}{16}$	$\frac{3}{8}$	$\frac{1}{4}$	$\frac{1}{8}$
6	2	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{16}$
8	3	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{16}$
10	$3\frac{1}{2}$	$\frac{5}{16}$	$\frac{5}{8}$	$\frac{3}{8}$	$\frac{1}{4}$
12	4	$\frac{5}{16}$	$\frac{5}{8}$	$\frac{1}{2}$	$\frac{5}{16}$
14	$4\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{4}$	$\frac{1}{2}$	$\frac{5}{16}$
16	$5\frac{1}{2}$	$\frac{1}{2}$	1	$\frac{1}{2}$	$\frac{5}{16}$
18	6	$\frac{1}{2}$	1	$\frac{5}{8}$	$\frac{3}{8}$
20	7	$\frac{5}{8}$	$1\frac{1}{4}$	$\frac{5}{8}$	$\frac{3}{8}$
22	$7\frac{1}{2}$	$\frac{5}{8}$	$1\frac{1}{4}$	$\frac{5}{8}$	$\frac{1}{6}$
24	8	$\frac{3}{4}$	$1\frac{1}{4}$	$\frac{5}{8}$	$\frac{1}{6}$
26	$8\frac{1}{2}$	$\frac{3}{4}$	$1\frac{1}{4}$	$\frac{5}{8}$	$\frac{1}{2}$
28	10	$\frac{7}{8}$	$1\frac{1}{2}$	$\frac{3}{4}$	$\frac{1}{2}$
30	10	$\frac{7}{8}$	$1\frac{1}{2}$	$\frac{3}{4}$	$\frac{5}{8}$
36	12	1	2	$\frac{7}{8}$	$\frac{3}{4}$

FIG. 11—DIMENSIONS FOR STRAIGHT FLANGES TO BE USED WITH STRAIGHT-SIDE WHEELS GUARDED WITH PROTECTION HOODS

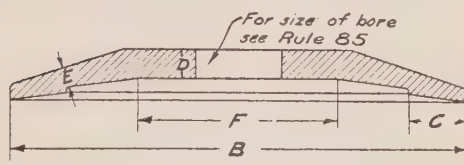
SAFE OPERATION OF WHEELS



Single Taper Wheel with one straight and one Tapered Flange



Double Taper Wheel with two Tapered Flanges



ALL DIMENSIONS IN INCHES

A Diameter of Wheel in Inches	B Minimum Outside Diameter of Flanges	C Radial Width of Bearing Surface		D Minimum Thickness of Flange at Bore		E Minimum Thickness at Edge of Recess		F Maxim'm Flat Spot at Center of Flange	G Approx. Diameter of Flat Spot or Hub of Wheel
		Minim'm	Maxim'm	For Double Taper Wheels	For Single Taper Wheels	For Double Taper Wheels	For Single Taper Wheels		
6	3	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{16}$	$\frac{3}{16}$	0	1
8	4	$\frac{5}{16}$	$\frac{5}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{1}{4}$	$\frac{1}{4}$	0	1
10	5	$\frac{1}{2}$	1	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{4}$	0	2
12	6	$\frac{1}{2}$	1	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{16}$	$\frac{5}{16}$	4	$4\frac{1}{2}$
14	8	$\frac{5}{8}$	$1\frac{1}{4}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{3}{8}$	$\frac{3}{8}$	4	$4\frac{1}{2}$
16	10	$\frac{3}{4}$	$1\frac{1}{2}$	$\frac{5}{8}$	$\frac{7}{8}$	$\frac{7}{8}$	$\frac{7}{16}$	4	6
18	12	1	2	$\frac{3}{4}$	1	$\frac{1}{2}$	$\frac{1}{6}$	4	6
20	14	$1\frac{1}{4}$	$2\frac{1}{2}$	$\frac{3}{4}$	1	$\frac{1}{2}$	$\frac{1}{16}$	4	6
22	16	$1\frac{3}{8}$	$2\frac{3}{4}$	$\frac{3}{4}$	$1\frac{1}{8}$	$\frac{9}{16}$	$\frac{5}{8}$	4	6
24	18	$1\frac{1}{2}$	3	$\frac{3}{4}$	$1\frac{1}{8}$	$\frac{9}{16}$	$\frac{5}{8}$	4	6
26	20	$1\frac{1}{2}$	$3\frac{1}{4}$	$\frac{3}{4}$	$1\frac{1}{8}$	$\frac{5}{8}$	$\frac{11}{16}$	4	6
28	22	$1\frac{3}{4}$	$3\frac{3}{4}$	$\frac{7}{8}$	$1\frac{1}{4}$	$\frac{5}{8}$	$\frac{3}{4}$	4	6
30	24	2	4	$\frac{7}{8}$	$1\frac{1}{4}$	$\frac{3}{4}$	$\frac{7}{8}$	4	6
36	28	2	4	1	$1\frac{3}{8}$	$\frac{7}{8}$	1	4	6

FIG. 12—SPECIFICATIONS FOR TAPER-SIDE FLANGES OF APPROVED TYPES

ment, however, does not apply to the so-called balancing flanges, which are made out of balance to offset the heavy side of a grinding wheel. Both flanges on one wheel should be of like diameter. Each flange must be recessed at the center at least 1/16-inch on the side next to the wheel for the distance specified in the following tables. The inner flange should be keyed, threaded, shrunk or pressed onto the spindle and the bearing surface must run true with the spindle axis. The bore in the outer flange should not be more than 0.002-inch larger than the spindle.

Dimensions for straight flanges to be used with straight-side wheels, guarded with protection hoods are given in Fig. 11. These specifications have been approved by the American Engineering Standards Committee. Taper-side flanges are used on wheels that cannot be guarded adequately with protection hoods. Specifications for flanges of this type as approved by the American Engineering Standards Committee are given in Fig. 12.

WHEEL-OPERATING RULES

The following practical suggestions are for the safe operation of grinding wheels:

RESPONSIBILITY FOR WHEELS USE

Competent men should be assigned to the mounting, care and inspection of grinding wheels and machines.

INSPECTION AFTER BREAKAGE

Whenever a grinding wheel breaks, a careful inspection shall be made to make sure that the hood has not been damaged, nor the flanges bent or sprung out-of-true or out-of-balance. The spindle and nuts also should be inspected carefully.

REPLACING OF HOODS

After mounting a new wheel, care should be taken to see that the hood is properly replaced.

STARTING NEW WHEELS

All new wheels shall be run at full operating speed for at least one minute before applying the work, during which time the operator shall stand at one side.

SAFE OPERATION OF WHEELS

APPLYING WORK

Work shall not be forced against a cold wheel, but applied gradually, giving the wheel an opportunity to warm and thereby minimize the chance of breakage. This applies to starting work in the morning in cold rooms and to new wheels which have been stored in a cold place.

TEST FOR BALANCE

Wheels should be tested occasionally for balance and rebalanced if necessary.

WHEEL TRUING

Wheels worn out-of-round shall be trued by a competent man. Wheels out-of-balance through wear, which cannot be balanced by truing or dressing, shall be removed from the machine.

WET GRINDING WHEELS

Wheels used for wet grinding should not be allowed to stand partly immersed in water. The water soaked portion may throw the wheel dangerously out of balance. All wet-tool grinders which are not so designed as to provide a constant supply of fresh water shall be drained thoroughly at the end of each day's work and a fresh supply provided before starting.

SIDE GRINDING

Grinding of the flat sides of straight wheels is often hazardous and it should not be permitted on such operations when the sides of the wheel are worn appreciably or when any sudden or considerable pressure is brought to bear against the sides.

DRESSER GUARDS

Wheel dressers, excepting the diamond type, shall be equipped with guards over the tops of the cutters to protect the operator from flying pieces of broken cutters or wheel particles.

SPINDLE LUBRICATION

Care should be exercised to prevent the spindle from becoming heated to such an extent that it will damage the wheel.

WORK RESTS

The work rests on a machine used for general off-hand grinding, tool sharpening, etc., should be kept adjusted to within $1/32$ -inch of the wheel face. Otherwise the work is liable to become wedged between the wheel and the work, which is sure to cause the wheel to fracture. The rests should be examined occasionally to make sure that they are adjusted properly and the holding screws should be set up securely. Unusually it is necessary to adjust the rests every time the wheel is dressed.

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